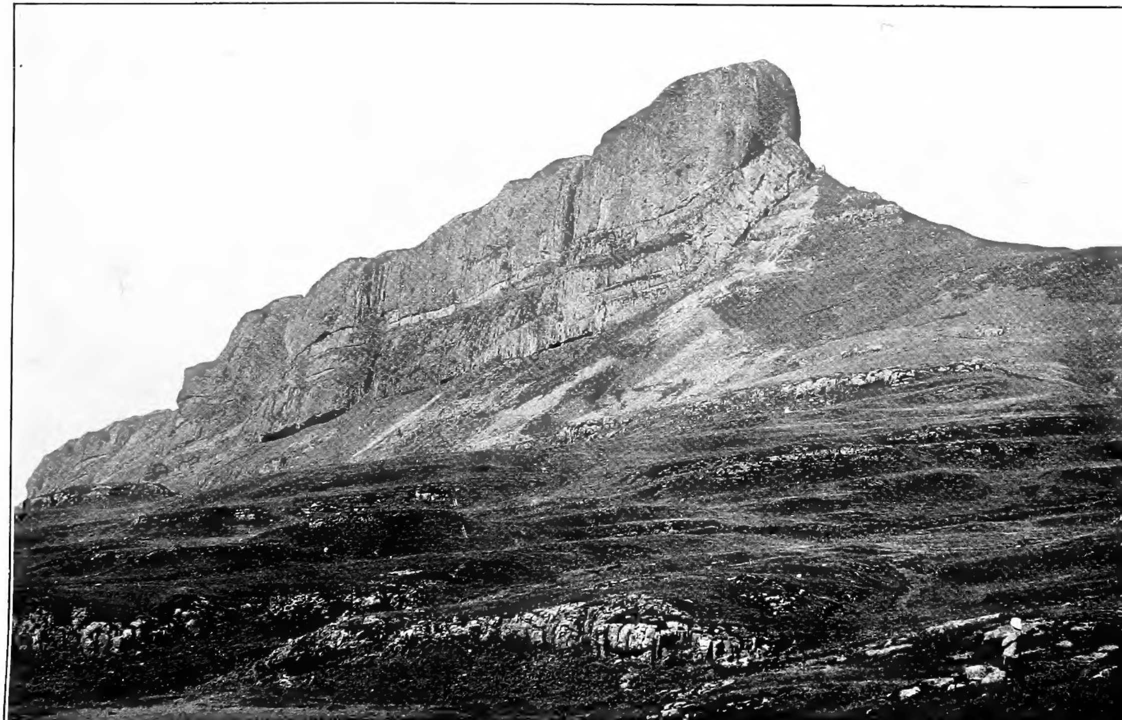
SCENERY OF SCOTLAND



THE SCUIR OF EIGG, FROM THE SOUTH-EAST.

Frontispiece

THE

SCENERY OF SCOTLAND

VIEWED IN CONNECTION WITH ITS PHYSICAL GEOLOGY

BY

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THIRD EDITION

WITH FOUR MAPS AND NUMEROUS ILLUSTRATIONS

London

MACMILLAN AND CO., LIMITED

NEW YORK: THE MACMILLAN COMPANY

1901

First Edition 1865
Second Edition 1887
Third Edition 1901

PREFACE

FIVE-AND-THIRTY years ago the thoughts of geologists in this country were turned more earnestly than they had ever been before to the great problems of topography, and more particularly to the origin of valleys. In 1862 Jukes published his memorable paper on the *River-Valleys of the South of Ireland*, which may be regarded as the starting-point of all subsequent research on the subject. The following year there appeared the first edition of the *Physical Geology and Geography of Great Britain*, by my former colleague and chief, Sir Andrew C. Ramsay, wherein the potency of denudation as a factor in the evolution of scenery was ably maintained. Papers enforcing similar doctrines were given to the world by my colleagues, Dr. Foster, Mr. Topley, and Mr. Whitaker. Though these views were only a reiteration and more detailed elaboration of the principles laid down by Hutton and Playfair, and were acknowledged to be so by those who espoused them, they encountered much opposition. It was whilst the controversy they evoked was in full force that the first edition of the present volume appeared—in 1865.

The interval which has since slipped away has witnessed a great change in the attitude of geologists

towards questions of topography. The views which, in concert with my colleagues in the Geological Survey, I had been led to adopt from close and constant examination of the evidence, are now generally accepted as part of the common stock of geological knowledge. For this recognition it is a pleasure to admit that they are largely indebted to the powerful and independent support they have received from the labours of the geologists who, following in the wake of my honoured friends the late J. S. Newberry and the veteran Major Powell, have explored the western regions of the United States. Had the question in dispute been first studied in that marvellous country of mesas and cañons, there would never have been any dispute about it. The truth is there proclaimed with an impressiveness almost bewildering to one whose experience has chiefly lain among the more ancient and convoluted rocks of Western Europe. All the more honour, therefore, to those who found the solution of the problem in the much less favourable field of European geology.

In the Eastern States of the Union the study of the subject has in more recent years been prosecuted with much vigour, and the same principles of interpretation have been applied with excellent results to that part of the New World. At the same time a technical topographical nomenclature has there been devised, which I do not adopt, as it seems to me unnecessary, and calculated rather to obscure than to simplify the investigation, affecting a precision which finds no counterpart in nature, and involving theoretical conceptions which may not always be well founded.

The present work was, I believe, the first attempt to elucidate in some detail the history of the topography of a country. The principles applicable in the British Isles have been found to be of universal significance, and thus the illustrations of them gathered in this country have a value both to the student who investigates this branch of geology and to the general reader who may be more specially interested in the historical development of the science.

Since the first edition appeared a large part of my time has been devoted to a further study of the history of scenery. My official duties have enabled me to pursue the examination of the evidence into the nooks and corners of almost every parish in Scotland, as well as into most parts of England, Wales, and Ireland. I have likewise carried on the investigation on the continent of Europe at many points from the north of Norway to the shores of the Mediterranean, and from the Faroe Isles eastwards to the Caucasus. But above all, it has been my good fortune to have been able to extend the research into Western America, and to have learned more during my months of sojourn there than during the same number of years in the Old Country.

The result of this accumulated experience has been to convince me, if possible, more firmly than ever, of the soundness of the principles for which I contended in the first edition of this book. The original volume having been for many years out of print, I was repeatedly urged to allow it to be reprinted in its original form. But though the principles remained

unchanged, my knowledge of the country had become so very much wider and more detailed that it seemed best to wait until such leisure came as would allow the fruits of this enlarged experience to be made use of in the book. At last I was able thoroughly to revise, in large measure to rewrite, and greatly to amplify the old chapters, and to publish a second edition in 1887. In one important respect the volume now differed from its previous form. In order to make it more useful and convenient to the geological traveller in Scotland, I drew up an Itinerary of routes through the country, with the view of guiding the visitor or the student to those features which are of greatest interest in regard to the questions discussed in the book.

The first edition was dedicated to my honoured chief and large-hearted friend, Sir R. I. Murchison, who died in 1871. His successor, Sir A. C. Ramsay, with whom during the writing of that edition I had so many profitable discussions, has likewise passed away. Jukes, who led us all in the new crusade, has long been dead. Scrope, the gentle and sagacious adviser and helper of younger men, who fully seventy years ago proclaimed the truth about the origin of valleys, has passed away. Lyell too, and Sedgwick, Phillips, Prestwich, and others, to whom we looked up with such veneration and affection, have one by one disappeared. There is a melancholy pleasure in thus once more associating the names of these leaders with a little volume in which they were pleased to take an interest.

The present edition has been carefully revised and

considerably enlarged by the introduction of fresh material derived from continual traverses of the country. The number of illustrations, taken chiefly from my note-books, has been largely increased. For the excellent photograph which is reproduced in the frontispiece I am indebted to Mr. A. S. Reid, who has been so successful with his camera in the delineation of geological structure. The maps accompanying the volume are new, and have been prepared by Mr. J. G. Bartholomew with his usual skill and accuracy. In addition to a new geological map, there is given a map of the glaciation of Scotland, likewise one of the broad topographical features of the country, and one showing the distribution of the vegetation in relation to the topography.

GEOLOGICAL SURVEY OFFICE, LONDON,
28th December 1900.

FROM THE PREFACE TO THE FIRST EDITION (1865)

"To trace back, if that might be, the origin of the present surface of the country, and by working out the structure of the rocks, to contrast the aspect of the land to-day with its condition in former geological periods, has been to the author of these pages the delightful occupation of years. The writing of this volume has thus gone on side by side with daily labour in the field, amid all the changes of scene and surroundings that fall to the lot of a member of the Geological Survey.

"The principles which have guided me in the following investigation are far from new: they were laid down long ago by Hutton and Playfair, and they have recently received fresh illustration from the pen of Professor Ramsay. I can claim nothing more than to have tried in some detail to develop these principles in an inquiry into the origin of the existing scenery of Scotland. The views to which I have been led, however, run directly counter to what are still the prevailing impressions on this subject, and I am therefore prepared to find them disputed, or perhaps thrown aside as mere dreaming. That in searching for a pathway through a field of scientific research wherein the travellers have as yet been few, one can hardly fail to go here and there astray, that he must needs miss much by the way, and that a few steps to either side would sometimes have brought him out of the cloud of doubt and uncertainty through which at the time no outlet could be

seen, will by none be more frankly admitted than by the traveller himself. Yet in spite of these mishaps, he may believe that on the whole his journey has been a progress in the right direction, and that even his errors may not be without their use in pointing out the right track to other explorers. Such at least is the hope in which I lay these chapters before my brethren of the hammer."

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PART I

LAND-SCULPTURE IN GENERAL

To roam at large among unpeopled glens
And mountainous retirements, only trod
By devious footsteps; regions consecrate
To oldest time! and while the mists
Flying, and rainy vapours, call out shapes
And phantoms from the crags and solid earth;
. . *and while the streams*
Descending from the region of the clouds,
And starting from the hollows of the earth
More multitudinous every moment, rend
Their way before them—what a joy to roam
An equal among mightiest energies!

WORDSWORTH, *Excursion*, b. iv.

CHAPTER I

INTRODUCTORY

Among the many forms of scenery that vary the surface of the earth, crags and mountains have from time immemorial impressed most vividly the human imagination. The lower grounds where man passes his existence are liable to continual change. He sees shores worn away by the sea, plains devastated and strewn with silt by floods, and river-banks eaten away by the streams that pass them. He himself too helps to transform the landscape. He ploughs up peat mosses, turns wet bogs into fertile farms, cuts down forests, plants new woodlands, covers the valleys with meadows, cornfields, and orchards, graves the country with lines of roadway, and builds all over the land his cottages, villages, and towns. But high above the din and stir of his feverish life, the great mountains rise before him with still the same forms of peak and crag that were familiar to his ancestors long centuries ago. While the outlines of the lowlands are touched with the instability that marks everything human, these far heights seem to remain impassive and unaffected, as if the hand of time had passed them by. Hence the everlasting hills have ever been favourite emblems, not only of grandeur but of immutable permanence.

And yet the mountains bear on their fronts the memorials of change which have not altogether failed to catch the eye even of the most untutored races. Their grim, naked cliffs and splintered precipices, their yawning defiles and heaps of

ruin, have always appealed to the fancy and the fears of men. These striking natural features in old days suggested legends and superstitions which are of interest, not only as the characteristic mental efforts of an early stage of human development, but as embodying the special parts of mountainous landscape that most potently excite the imagination in the childhood of a people. The days of legend and superstition have passed away, but the lonely glens and dark precipices of a mountainous region still make their mute appeal to us, as they did to our forefathers. We have cast aside the old fables and romances, yet the same ineradicable desire to find an explanation of natural appearances, which prompted these fanciful inventions, still burns within us, and compels us to ask in our own way the same questions. We cannot shake off the feeling of vague awe which falls upon us in a great mountain range, as we stand face to face with some of the sublimest scenery on the earth's surface. The magnitude of the scale of nature and the utter loneliness of the vast mountain-world powerfully affect us. But deep beneath the feelings thus evoked lies a more or less consciously felt mental unrest in presence of the mystery of the cause of such stupendous features. The gentle undulations of a lowland landscape may never start in the mind a passing thought as to their origin. The stern broken features of the mountains, however, arrest our attention and excite our imagination as we try to picture to ourselves how they came into existence.

Now that fable and legend no longer command credence, the natural answer of most ordinary observers to the question of the origin of the more rugged features of landscape calls at once upon vast primeval convulsions that suddenly upheaved the mountains, rent open ravines and glens for the rivers, and unfolded wide valleys to receive and remove the drainage to the lower grounds and the sea. These paroxysms are vaguely looked upon as in some way a record of the first grand uprise of the dry land out of chaos. The popular belief for centuries

past, and probably still in the greater part of Christendom, is well expressed by Milton :—

"When God said,
'Be gathered now, ye waters under heaven,
Into one place, and let dry land appear!'
Immediately the mountains huge appear
Emergent, and their broad bare backs upheave
Into the clouds; their tops ascend the sky.
So high as heaved the tumid hills, so low
Down sunk a hollow bottom, broad and deep,
Capacious bed of waters." [1]

But even amid the light of science, with recognition of the truth that instead of being remnants of a primeval chaos, mountains are of many different ages, and have, indeed, arisen at intervals all through the geological past, the belief in titanic convulsion as the main factor in the shaping of the contours of the dry land still holds its ground. There is an air of grandeur and simplicity about this explanation which has made it popular. It deals with that dreamland of conjecture lying far beyond the pathways of sober science, where facts are not needed for either the foundation or superstructure of theory. Requiring no scientific knowledge or training, it can be easily appreciated, and may be readily applied to any region by those to whom the very name of geology is unknown. Even where some knowledge of the results of geological investigation has been obtained, and the fact is familiar that the present surface of the earth contains the record of a vast succession of terrestrial changes, the influence of the old fondness for cutting the gordian knot of geological problems by recourse to earthquake and upheaval, still makes itself felt. Men are unwilling to recognise that the question of the origin of scenery is really so complex as those who have most closely studied it maintain it to be. And so they make short work of the difficulties, referring all the intricacies in the configuration of the land to the results of subterranean convulsion.

[1] *Paradise Lost*, book vii. l. 282.

Now it must be frankly conceded that by far the larger part of the dry land has once been under the sea; that, indeed, it mainly consists of materials—hardened mud, sand, gravel, and limestone—which accumulated on the floor of the sea in vast sheets many thousands of feet in thickness, and that its present position above the sea-level is due to underground movements. The sea-bed has again and again been ridged up into land, and even on the flanks of the highest mountain-chains, portions of that old sea-bed may be seen towering into lofty crags, where glaciers creep and snow-fields lie. But when it is further asserted that the existing topographical features are the direct consequence and memorial of that upheaval, the trained geologist at once and emphatically answers No. If such a relation between the present configuration and former earth-movements really exists as is assumed, it should be proved on proper evidence. The ground should be examined, and made to tell its story. The mere fact that the dry land consists mainly of marine sediments demonstrates the fact of upheaval. But the effect of the upheaval on the ultimate details of topography is a question of geological physics which must be worked out by an appeal to the available facts.

Now if we thoughtfully consider the system of contours in any portion of the land, we cannot but be struck with the evidence it presents of the most nicely adjusted symmetry. Hill and mountain, valley and glen, are so grouped that each falls into its natural, and, as it were, prearranged place in the topography. There is certainly no evidence that random, haphazard operations have in any way affected the delineation of the topographical features of the land. Whatever may have been the nature of the causes that were in operation, the results which they have brought about point to the paramount influence of some agent that worked with constant reference to the drainage-lines. The system of these lines is one of the most remarkable characters in the terrestrial areas of our planet.

From the high grounds, the gathered rains and melted snows and outflowing springs descend in thousands of water-courses, which, beginning with the tiniest runnels, and ranging through a vast gradation of rivulets and brooks and tributary streams, reach at last the broad-breasted river that bears their united burden to the sea. Each of these threads of water keeps its own channel, and the system of water-channels that has been graven into the solid land shows the most marvellous harmony in every minutest detail.

Each drainage-line follows a depression on the surface of the land. The smaller runnels have beds sometimes only just deep enough and wide enough to carry their water; but the larger rivers flow in capacious valleys. There is everywhere, indeed, a more or less close relation between the volume of the stream and the size of the hollow along which it descends. The form and dimensions of the hollow may vary indefinitely, but the general symmetry of the system is maintained. No ordinary map can adequately represent these hollows, but it aims at depicting at least the larger streams which flow in them. The map consequently gives us little information as to the form of the valleys. These may be wide, open, smooth, with gently shelving sides, or they may be only narrow gorges, in which the waters toil between naked walls of rock. It will be observed that the most precipitous ravines fall easily into the general plan, and lie as naturally in the pathways of the streams as do the widest straths. Evidently this close harmony between the shape of the ground and the drainage-lines cannot be the mere fortuitous result of some operation that took place entirely independent of the flow of water. The valley-systems and drainage-lines are so intimately related that we are compelled to trace them backward to some common origin.

An attentive study of what is now taking place in the channels of brooks and rivers shows that running water, by bearing along sand and gravel, rubs down the rocks over which it flows, and thus deepens and widens the bed that contains it.

All over the globe, and in the most widely diverse kinds of material, this process of excavation may be seen in progress. From the early ages of human observation the fact that water wears down the hardest rocks has been familiar. But the connection of this fact with the history of valleys was not fully perceived till towards the close of the eighteenth century. And though there are many regions where the process is far more wonderfully displayed, it was first clearly understood and authentically proclaimed in Scotland. Hutton, in his immortal *Theory of the Earth*, declared that "the mountains have been formed by the hollowing out of the valleys, and the valleys have been hollowed out by the attrition of hard materials coming from the mountains."[1] His friend and illustrator, Playfair, expounded and enforced the same doctrine in his own characteristically lucid and elegant language. "If, indeed," he says, "a river consisted of a single stream, without branches, running in a straight valley, it might be supposed that some great concussion or some powerful torrent had opened at once the channel by which its waters are conducted to the ocean; but when the usual form of a river is considered, the trunk divided into many branches, which rise at a great distance from one another, and these again subdivided into an infinity of smaller ramifications, it becomes strongly impressed upon the mind that all these channels have been cut by the waters themselves; that they have been slowly dug out by the washing and erosion

[1] *Theory of the Earth*, vol. ii. p. 401. Since the last edition of the present volume appeared, the Geological Society of London has published the portion of the MS. of the third volume of Hutton's *Theory* which has been for many years in the Society's possession. It includes three chapters of special interest in relation to Scottish geology and landscape—one dealing with the author's famous visit to Glen Tilt; another with his journeys in Carrick and Galloway for the purpose of investigating the granite of that region; and the third with the geology of the Island of Arran, of which a remarkably full and suggestive description is given. The Huttonian doctrines on denudation and land-sculpture are enforced in these chapters from Scottish examples drawn from the Highlands, the Southern Uplands, and Arran. See more particularly pp. 26-29, 257-67.

of the land; and that it is by the repeated touches of the same instrument that this curious assemblage of lines has been engraved so deeply on the surface of the globe."[1] The independence of each hydrographical basin, the nice adjustment of all its parts, the union of minor in larger basins, and the combination of the whole in one great system of drainage, point not to random outbreaks of underground violence, but to the graduated and orderly operations of the streams themselves.

A familiar analogy to this process of valley-excavation may often be seen on flat, sandy, or muddy shores from which the tide has retired. The water that oozes out from below high-tide mark gathers into tiny runnels; these gain in size and speed as they descend the beach, often coalescing, and then, with their augmented current, cutting for themselves narrow and tortuous channels in the sand. They may be seen undermining their banks, forming miniature gorges, and sweeping along their load of sediment to throw it down on any hollow or flatter part of the beach. Thus, before the tide rises again to efface the whole, a complete drainage-system may be carved out of the sand, which will serve as a kind of model of the drainage-system of one side of a country or a continent.

When, from these general considerations, we proceed to the examination of the actual surface of the land, one of the first and most striking features to present itself to notice is the evidence of universal loss of material. Not only from the valleys, where running water is visibly engaged in loosening and transporting debris derived from solid rocks, but everywhere from the general surface of the land, a vast amount of rock can be demonstrated to have been removed. Abundant evidence of the truth of this statement will be furnished from the surface of Scotland in the following chapters. The abstraction of

[1] *Illustrations of the Huttonian Theory*, § 99. This classic ought to be read and re-read by every geological student. As a model of terse, clear, and elegant exposition of the truths of physical geology it still stands unrivalled.

material cannot be accounted for by underground disturbance. It is, in fact, most strikingly displayed where the rocks retain their original horizontality; where, consequently, though they have been uplifted, they have not been crumpled or disarranged, and where, therefore, the idea of subterranean convulsion is completely excluded from consideration as a factor in the production of the present irregularities of contour. The formation of the valleys has proceeded concomitantly with a general degradation of the surface of the land. The causes of this degradation are not obscure. We see them in full working order at the present time all over the globe, wherever land rises above the surface of the sea. They are to be recognised in the action of the air, rain, frost, springs, rivers, glaciers, and the sea. Hence the erosion of valleys would appear to be only a part of a vast and complex process of waste from which the surface of the land is continually suffering. We do not need to appeal, therefore, to unknown or recondite causes to account for the topographical features that diversify the dry land. The very agents that are working there now would evidently produce such features, if allowed long enough time for the task.

Fortunately we are not left to mere conjecture on this subject. The material removed from the surface of the land finds its way to rivers which transport it to the sea, where it finally settles down upon the sea-bottom. The amount of it annually removed in this manner is a measurable quantity, and has been ascertained with some approach to accuracy by a determination of the proportion of sediment in the water of a few of the larger rivers of the globe. The Mississippi, as a typical river, draining a vast region wherein the climates, rocks, and elevations greatly vary, has been taken to represent a tolerably fair average of river-action. This stream, according to measurement and computation, carries every year into the Gulf of Mexico a quantity of mineral sediment equivalent to the lowering of its whole drainage basin by $\frac{1}{6000}$th part of a

foot of rock. At this rate, an amount of material equal to the loss of one foot from the surface of the whole basin would be worn away and carried to the sea in 6000 years. If the average height of Europe be taken at 940 feet, and if we could suppose this continent to be continuously worn down at the present rate of degradation in the Mississippi basin, then the whole of Europe would be reduced to the sea-level in little more than five and a half millions of years.

We have no reason to suppose that the general lowering of the surface of the land is advancing more rapidly now than it formerly did. Indeed, it may once have been faster than it is now. But even at the present rate, we are forced to admit that as every part of the land is undergoing degradation, no portion of its actual surface can possibly be of great antiquity. Terrestrial areas doubtless still exist where they existed long ages ago, but their surface has been continually altering, and unless renewed by upheaval, the dry land itself must in the course of a very few millions of years be everywhere worn down to the level of the sea. Obviously, then, the attempt to recognise in the present configuration of an ordinary land-surface the forms impressed upon it by primeval upthrows that raised it from the sea-level, is really not deserving of serious consideration, and has long been abandoned by all competent observers.

The problem of the origin of the scenery of any part of the earth's surface must obviously include a consideration of the following questions:—(1) The nature of the materials out of which the scenery has been produced. (2) The influence which subterranean movements have had upon these materials, as, for instance, in their fracture, displacement, plication, and metamorphism, and whether any evidence can be recovered as to the probable form which they assumed at the surface when they were first raised into land. (3) The nature and effect of the erosion which they have undergone since their upheaval; and (4) the geological periods within which the

various processes have been at work, to the conjoint operation of which the origin of the scenery is to be ascribed.

It is obvious that the history of the rocks is a subject entirely distinct from that of the forms which these rocks now wear on the surface of the land. Much as we know regarding the various systems and formations into which the rocks of the earth's crust have been grouped, we are still comparatively ignorant of the history of the surface of the land. The physical conditions and much of the organic life of the Silurian, Devonian, and Carboniferous periods, for example, are tolerably well ascertained for large areas of the earth's surface; but when we are asked to say how Silurian, Devonian, and Carboniferous rocks have come to be fashioned into the contours of the land which they now form, and what has been their history since they uprose from the sea; still more, if we are asked where the land of those ancient periods lay, and what it was like, we cast about for an answer, and learn that it is not easy to find. The general principles involved in these questions may be clear enough, but the application of them to any particular example involves us in innumerable difficulties. The more the subject is pondered over, the more remote does the first origin of the present topography become—the farther back are we led into the geological past, and the greater are the demands on our imagination in picturing to ourselves conditions of geography and forms of surface that preceded those which now prevail. But it is only from actual concrete examples that the history of the surface of the land can be interpreted.

The present volume is accordingly devoted to an inquiry into the history of the scenery of Scotland. The landscapes of that little corner of Western Europe will always be regarded with special interest. To every one they are memorable as the theatre where the battle of national liberty has been fought, and whence the effects of victory have profoundly influenced the progress of freedom and free institutions all over the globe. To the lover of romance they teem with associations that have

been embodied in a literature now familiar not only wherever English is spoken, but wherever education has made its way. The pilgrim who seeks them for their natural beauty finds among them scenes which have few rivals in Europe for wealth of colour, if not for variety of form. The student of æsthetics sees in them the source of that inspiration which, in kindling the language of Scott, did so much to spread abroad in modern society an appreciation and affection for natural scenery. And lastly, the student of geology looks on them with veneration as embodying the materials which led Hutton and Playfair to their conclusions, and paved the way for all those who have subsequently investigated the phenomena of denudation and the origin of landscape.

To subject Scottish scenery to dissection and analysis may seem a sort of ruthless proceeding, like that of the pedant who insists on cutting a flower to pieces and showing you its structure in order that you may adequately enjoy its beauty. But, fortunately, let the formal geologist do and say what he likes, the beauty and grandeur of the landscapes remain unimpaired. Nay, if he can only present his results in simple and intelligible guise, they will be found in no degree to lessen the charm of the scenery. He cannot diminish the romance that hangs like a golden mist over the country; on the contrary, he reveals another kind of romance, different indeed in kind, but hardly less attractive, wherein firth and fell, mountain and glen, glow with all the fervour of a poet's dream.

Whether I shall succeed in the attempt to realise this ideal task the reader must judge. Let me, however, assure him at the outset that if the human associations of the land are uppermost in his mind as he wanders through it, my sympathies are wholly with him. And if, after perusing my chapters, he finds no enduring interest in the subject of which they treat, but turns back again with renewed interest to the realm of history and romance, I shall make no appeal from his judgment. I would only have him believe that it is, nevertheless, possible

to find ample room in one's mind for both classes of associations, and to experience relief and solace now from the one kind and now from the other. The natural features of Scottish scenery would of themselves powerfully affect us, but they are generally closely linked to some association with the events of history, with the creations of fiction, or with the dreams of poetry. There is thus a double charm about them, and it is often hard to say which portion of it is their more powerful element.

The materials out of which the landscapes of Scotland have been framed, and the influence of subterranean movements upon them, will be described in later chapters in connection with the three regions into which the country may naturally be divided, each district having its own peculiarities of geological structure. But the tools which Nature has wielded in carving these materials into their present forms have been everywhere at work, and may therefore be considered for the country as a whole. Accordingly, before entering upon a discussion of the characteristics and origin of the various types of Scottish scenery, I propose first to describe briefly and in general terms the operation of the various agents which, acting upon the surface of the rocks, produced the details of the topography, and as far as possible to take the illustrations of their mode of working from what may now be seen going on in Scotland.

CHAPTER II

NATURE'S SCULPTURE-TOOLS—AIR, RAIN, RIVERS, SPRINGS, FROST

THE process by which the scenery of a country is produced may be compared to sculpture. In the fashioning of a statue, the block of stone must first be lifted out of its bed in the parent rock, before the sculptor's tools can be used upon it. Apart from the design and workmanship, the aspect of the statue will primarily depend on the nature of the material employed. Long practice has shown that statuary marble is best adapted for the purpose of the sculptor's art. If conglomerate, or sandstone, or porphyry, or granite were chosen, the effect would in each case be different. So in the case of the dry land. There must first be an uplifting of the ground above sea-level, and then Nature's tools will slowly carve its surface into the characteristic terrestrial shapes. The ultimate details of these shapes will be greatly influenced by the nature of the material, each kind of rock revealing its own peculiar characters and influence in the general process of land-sculpture. But much also will depend upon the particular tools which Nature may use, and on the energy with which she wields them. The tools that have been most effective in the carving of the land are Air, Rain, Frost, Springs, Rivers, Glaciers, and the Sea. Let us watch each of them at work.

Air and Rain

Long exposure to the air tells even upon the most obdurate kind of stone. An old building always shows more or less manifest proofs of decay, insomuch that if these are not conspicuous, we instinctively begin to doubt whether it can really be old. This decay is known by the name of "weathering." It is a complex process, partly chemical, partly mechanical. Great and rapid changes of temperature tell powerfully upon the outer surfaces of rocks. Heated during the day under a strong sun, and chilled by quick radiation at night, these surfaces are in such a state of strain that they often crumble down, or even crack and peel off. Still more general and effective is the alternate soaking and desiccation they undergo. Saturated at one time with rain, and then baked in dry weather, the component particles are gradually loosened, and fall away into sand or clay. The influence of frost, too, in climates where the temperature sinks to the freezing point, plays a large part in the process of weathering. The moisture imprisoned between the grains and in the crevices of rocks expands in passing into ice, pushes the grains apart, and thrusts its wedges of ice into the crevices, so that when thaw comes the loosened materials fall asunder. When these are dried their lighter particles may be blown away by wind. But rain probably plays the most important part of all in the degradation of the general surface of the land. Its influence is twofold, partly in chemically dissolving out the soluble ingredients in the rocks on which it falls, and partly in mechanically washing away the loosened materials.

Nowhere can the nature of weathering be more conveniently and instructively studied than upon ancient masonry, and notably among the gravestones of a churchyard. Originally as they left the hands of the mason, the stones of a wall or the slabs and pillars of a monument were smoothly dressed, or even polished. We can, therefore, compare their present with their

original condition, and mark the nature and amount of the disintegration they have suffered. Moreover, when the dates of their erection are preserved, we obtain from them a measure of the rate of waste.

Twenty years ago I made some researches among graveyards in towns and in the country in different parts of Scotland, with the view of obtaining some data for the discussion of the question of weathering. Great differences are there observable in the character and amount of disintegra-

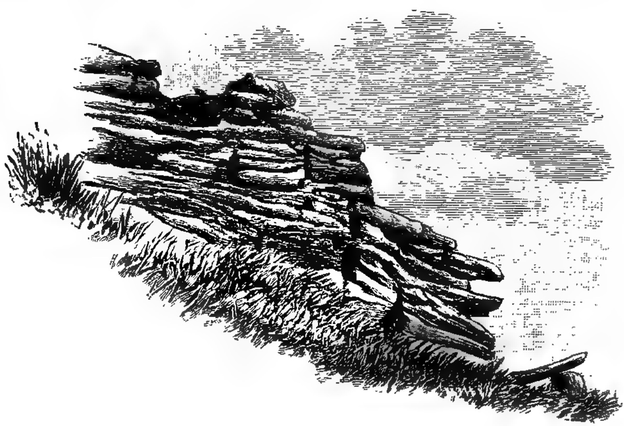

FIG. 1.—Granite weathering along its joints near the top of Ben na Chie, Aberdeenshire.

tion, according to the nature of the stone employed. By far the most easily destructible material in Scotland is white marble. The smooth polish given to it by the sculptor is effaced in a few years; the surface of the stone becomes rough and granular, so as to look like a sandstone, and if the hand is passed over it, the loosened grains of calcite, that are ready to fall, are at once swept off. Further exposure leads to the furrowing of the marble on the side most exposed to the rain, until the natural inequalities in the texture of the stone entirely replace the artificial surface. In some cases, a crust of soot and dust

forms on the marble and apparently protects it, but the stone decays underneath, and, as the crust breaks off, crumbles into mere sand. Where a slab of marble has been fixed within a sandstone frame, it has frequently bulged and at last burst in the centre, and has thereafter rapidly yielded to the weather.

Some impressive examples of these changes may be seen in the older churchyards of Edinburgh. The handsome monument erected in the Greyfriars' Churchyard to the great Joseph Black at the beginning of the nineteenth century, though partially protected from the weather, was in 1880 in some places illegible. As I examined the marble of the tomb and its Latin inscription that records the genius of the discoverer of carbonic acid, I could not but reflect on the curious irony of Nature, that has furnished in the corrosion of his monument her own testimony to the truth of his discovery. As the result of my inquiries, I found that in such a climate as that of Scotland, marble tombs freely exposed to the weather are destroyed in less than a century. The rate of superficial disintegration amounts sometimes to about a third of an inch in that time.[1] The limestones which occur so abundantly in the geological structure of the Highlands and Lowlands must thus be liable to great and rapid decay. Where they emerge at the surface they frequently present a singular assemblage of pale projecting knobs, like mouldering tombstones, the rock between having been removed in solution. In many places, too, they have been eaten away far below the surface, so that the ground beneath is honeycombed with tunnels and cavernous spaces, into which the surface soil sinks down (swallow-holes, sinks). Thus the outcrop of a limestone seam may be traced across a Highland moor by a line of such depressions, though the rock itself may never appear from beneath its peaty covering. Now and then in quarrying operations, sections are laid open of these dissolved spaces in limestones, which show how

[1] See my *Geological Sketches at Home and Abroad*, p. 182. In 1894 Black's tomb had become so ruinous that the rotted marble was replaced by sandstone.

the overlying materials subside into them. Such an instance is given in Fig. 2.

Sandstones being largely made use of for building and monumental purposes, many opportunities are afforded of examining their modes of weathering (see Fig. 8). Many of the more compact and siliceous kinds are remarkably durable, retaining their chisel-marks even after the lapse of two centuries.[1] Where a soluble or easily removable matrix, however, holds the component grains together, sandstone may be rapidly disintegrated; while, if divided by well-defined laminæ, the stone is pretty sure to split up or peel off along these planes of separation, as air, rain, and frost alternately attack it.

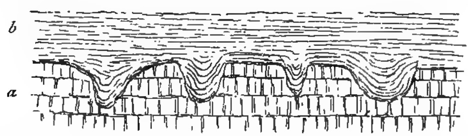

FIG. 2.—Carboniferous limestone (*a*), with "sinks" dissolved out of it by water percolating down the joints; into these hollows the overlying shales (*b*) have subsided. Lower Quarry, Closeburn, Dumfriesshire.

The crystalline rocks present many interesting varieties of weathering. The joints by which they are so abundantly traversed serve as channels for the action of percolating water and frost, and hence as planes along which the rocks are split open. In such a rock as granite, for instance, where one chief set of joints runs in the same general direction, the influence of weathering causes the rock to open along parallel lines that closely resemble those of masonry. Every one who has climbed granite mountains will recall such groups of opened joints as are represented in Figs. 1 and 12. In many cases, the action of the weather reveals internal structures that are invisible in freshly-broken portions of the stone. Characteristic examples of this action are supplied by the onion-like crusts that peel off

[1] As in the case of the tomb of Alexander Henderson in Greyfriars' Churchyard, Edinburgh (*op. cit.* p. 199).

from the spheroidal blocks into which many diabases and basalts weather. These groups of rounded exfoliating balls are a familiar feature among the eruptive rocks of the Midland Valley (Fig. 3).

There is no necessary relation between the hardness or softness of a stone and its durability under the attacks of the weather. Granite, basalt, limestone, and many other materials are much harder than soapstone, slate, and chloritic schist, yet they decay much more rapidly. Good illustrations of this difference may be seen among the graveyards in the Highlands, where different varieties of the schists have been used for tombstones. Thus at Peterhead an upright slab of clay-slate, erected between 1785 and 1790, retains its smooth polished face, and its lettering remains still sharply cut. Yet this stone can easily be scratched with a knife. The tombstone faces the south-west, and has therefore been fully exposed to the wind and rain, yet so little has it been affected that even its cubes of pyrites are only coated with a thin oxidised film and surrounded with a yellow stain on the slate. They have not sensibly altered the smooth flat surface of the stone. Varieties of potstone or *lapis ollaris*, which have long been quarried at St. Catherine's, on Loch Fyne, likewise retain their tool-marks for many generations. Yet these stones can actually be scratched with the thumb-nail.

Remarkable illustrations of the unequal advance of superficial disintegration are afforded by rocks composed of materials that vary greatly in hardness within a short space. Boulder-clay, moraine-stuff, and conglomerate, for example, which are made up of blocks of hard rock embedded in a softer matrix, are liable to have that matrix more rapidly cut away than the blocks enclosed in it, which consequently protrude from the cliffs, and sometimes form the capitals of tall pillars that are gradually cut by the rain out of the mass. Some excellent examples of these rain-eroded columns are to be seen in a group of ravines worn out of the Old Red Sandstone on the

right bank of the Spey above Fochabers (Figs. 4 and 5). At this locality also an instructive lesson may be learnt regarding the process of degradation and its comparative rapidity. Originally a hollow, probably a water-course, in the conglomerate was nearly filled with boulder-clay, but a

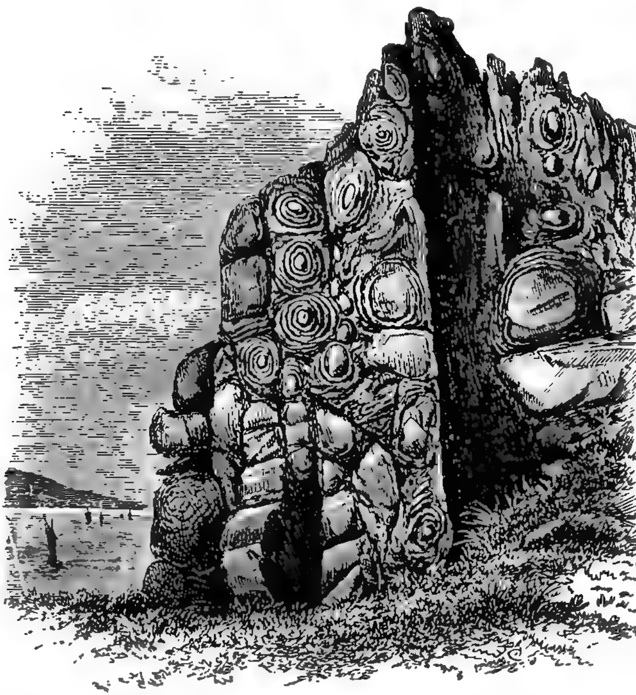

FIG. 3.—Spheroidal weathering of dolerite, North Queensferry.

sufficient depression was left to guide the drainage and give rise to a new water-course on the disappearance of the ice. Little runnels, flowing down the sides of the hollow, cut their way first through the boulder-clay and then through the scarcely more coherent conglomerate. In this way narrow tributary ravines have been dug out on the flanks of the main

gorge, and the intervening blocks are attacked and denuded by the weather. The runnels cut their way backward with such rapidity that a cart-road, with the wheel ruts still fresh upon it, had at the time of my visit in 1876 been trenched by gashes a yard or more in depth and several yards broad, and a new track had to be made round the head of the encroaching ravine.

While over the whole country the decay of the surface is in continual progress, the rotted material of the rocks is not allowed to accumulate upon them as a general cover, which in the end might shield them from further waste. It is dried and blown away as dust by the wind, or it is washed off into the nearest brook by rain. Of the reality of this universal loosening and transport of detritus from the high grounds to the sea, impressive illustrations may be witnessed during heavy rains. After weeks of dry weather everything looks baked and dusty. The soil crumbles into powder at a touch. Each fitful gust of wind raises a cloud of dust from roads and bare fields, or blows away the sand that has been loosened on the surface of naked stone. But the sky darkens, and at length rain descends. In a few minutes every channel on the roadway, every gully on the slopes, every runnel and water-course is the track of a muddy torrent which sweeps down into the nearest brook. The brooks, swollen from bank to brae by the sudden descent of such innumerable tributaries, rush along laden with the fine particles of soil and disintegrated rock, which they bear into the main stream of their drainage basin. And the rivers, dark with all this accumulated mud, bear it downward into the nearest lake or away out to sea. In a few hours, thousands of tons of sediment may be washed off the surface of a single parish. If now we allow the multiplying power of time to tell upon this process, we can easily perceive how vast must be the result even within a comparatively brief geological period.

It is evident that apart from the varying nature of the rocks,

and their rapidity or slowness in weathering, the lowering of the surface of a country by this action of air and rain cannot possibly proceed uniformly over the whole. Other things being equal, the rate of degradation will be regulated by the angle of declivity, being greatest where the slopes are steepest, and where, consequently, the mechanical force of descending rain is most powerful. On flat ground it must be reduced to a

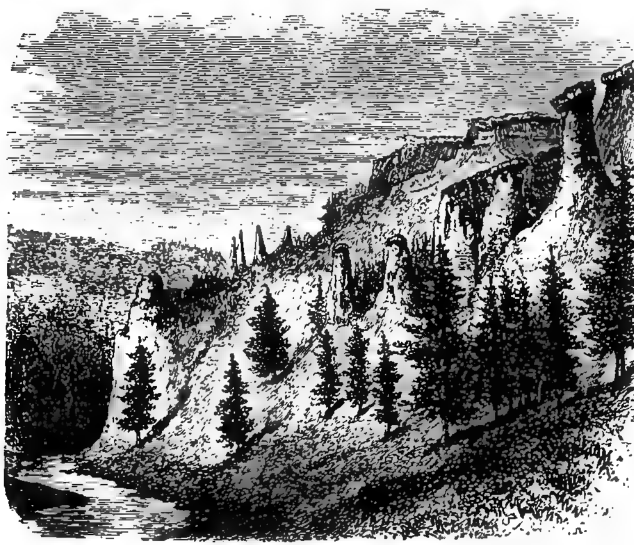

FIG. 4.—Rain-eroded pillars of Old Red conglomerate and boulder-clay, Fochabers.

minimum, not only because the motion of the rain is there feeblest, but also because in many places it is over these lower tracts that the detritus swept down from higher ground is strewn.

Besides its action in the slow disintegration of rocks, air plays a notable part when it blows across a country. Its influence on vegetation may be impressively seen along exposed coasts and on bare hillsides, where the trees and their branches are bent into one prevalent direction, away from the

quarter whence the wind chiefly blows (Fig. 6). In Northern Caithness, where trees have a keen struggle with the salt blasts that sweep over the land, the stunted woods look as if they had been mercilessly pruned into a sloping face, away from the prevalent gales. A high wind, by prostrating trees, will sometimes lay bare a whole hillside to the elements. The blowing down of woods upon low ground has so intercepted the surface-drainage that marshes have been formed, which have subsequently grown into peat-mosses.

The most familiar geological operation of wind is seen when, in dry weather, dust is raised from roadways and fields and borne along in the air. We probably do not adequately realise the extent to which this process contributes to the removal and redistribution of disintegrated rock and soil upon the surface of the land. More obvious are the results where prevalent breezes from the sea blow across low flat beaches of sand. Laid bare by the recession of the tide, and gradually dried on the surface, the sand is lifted up by the wind and carried landwards, where it gathers into dunes of wavy ridge and undulating hollow, which, like the crests and troughs of a billowy sea, run, in a general sense, parallel with the coast-line. Many creeks and wide bays along the coast-line of Scotland furnish illustrations of the

"Sand-built ridge
Of heaped hills that mound the sea."

Beginning at the far north of the kingdom, we find some striking dunes at the mouth of the Kyle of Durness (Fig. 7). Another strip of blown sand skirts part of the Dornoch Firth, and a still more extensive tract on the Moray Firth, between the Nairn and the Findhorn, has a peculiar interest from the fact that it has invaded and overwhelmed large spaces of once fertile land. The old barony of Culbin has in this way been entirely obliterated. "I have wandered for hours," says Hugh Miller, "amid the sand-wastes of this ruined barony, and seen

only a few stunted bushes of broom, and a few scattered tufts of withered bent, occupying, amid utter barrenness, the place of what, in the middle of the seventeenth century, had been the richest fields of the rich province of Moray."[1] The coast of Aberdeenshire is varied with wide stretches of drifting sands. One of these extends for several miles on both sides of Rattray Head, and another runs for some fifteen miles from near Slains to Aberdeen. Many a fair field has disappeared under the dunes, as these march inland. "The parish of Forvie," says Pennant, "is now entirely overwhelmed with

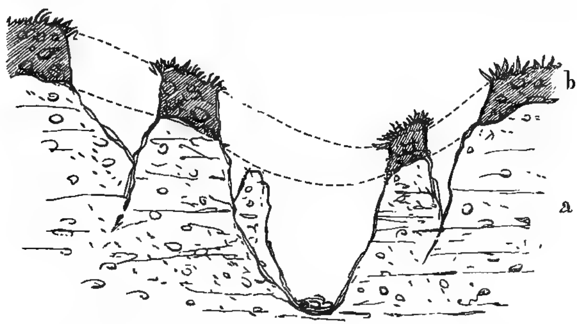

FIG. 5.—Section of a portion of the stream-course shown in Fig. 4. *a*, Old Red Conglomerate; *b*, Glacial Drift.

sand except two farms. It was in 1600 all arable land, now covered with shifting sands, like the deserts of Arabia, and no vestiges remain of any buildings except a small fragment of a church."[2] On the Forfarshire coast the blown sand mounds at the mouth of the Lunan Water have driven that stream perhaps a mile from its original position. The wide Tents Muir, between the Bay of St. Andrews and the mouth of the Tay, presents a remarkably good example of the parallelism of the successive sand-ridges with the line of the coast.

On the west side of the country many tracts of dunes also

[1] *Sketch-Book of Popular Geology*, p. 13.

[2] *First Tour* (1771), p. 144.

occur. They are particularly abundant in the southern half of the Hebrides, where the Atlantic breezes have built up an almost continuous strip of ridges, composed largely of white shell-sand, along the western coasts of Bernera and North and South Uist. Again, on the west sides of the islands of Coll and Tiree, and in Macrihanish Bay, Cantire, groups of sand-hills may be seen. Even in the comparatively sheltered basin of the Clyde, examples occur not less extensive than those of more open parts of the coast-line. The margin of Ayrshire, for fully fifteen miles between Stevenston and Ayr, is fringed with dunes, where the same melancholy tale of devastation is told. To the east of Stevenston, I have seen a roadway deeply buried under the loose drifting sand, and only traceable by the tops of the blackened decaying hedgerow on either side of it. The Wigtonshire shores are likewise mottled with dunes.

In connection with the subject of the blown-sand accumulations of the Scottish coast-line, I may refer to the remarkably interesting archæological discoveries which in recent years have been made in them. From those of Wigton and Culbin, in particular, thousands of objects have been recovered, ranging in antiquity from the Stone Age up to the reign of Queen Victoria. The constant shifting of the sand makes it continually cover up the present surface and expose old ones, so that objects of vastly different age may be buried almost side by side in the same deposit.

The mere mechanical force of the wind upon the surface of the land is probably nowhere in Britain more sensibly felt than among the bare and exposed Orkney and Shetland Islands. I have been astonished, when walking along the edges of the great precipices of the Island of Hoy, 1200 feet high (Fig. 19), to find scores of flat pieces of sandstone strewn across the moor. These fragments, weighing one pound or more, had been torn from the cliffs by a previous gale and swept upward and inland. Hence, besides the impetus of the breakers, hurricanes

of wind may have a considerable influence in the degradation of sea-cliffs. When to the force of the wind there is added the lashing of heavy storms of rain, the conditions are eminently favourable for the degradation of exposed rocks. The effects of these agencies may be impressively seen along the edges of the same precipices of Hoy. The yellow and red sandstones have there been carved into singularly picturesque forms of buttress and pinnacle, cornice and frieze. Here and there the rock has been actually perforated into arched openings, from which one can look over the wide Atlantic, and watch the

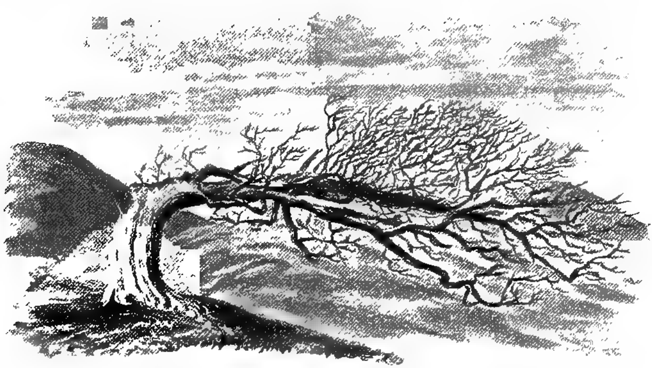

FIG. 6.—Old ash tree, sketched in a calm, Whitewell, Clitheroe.

successive lines of billow break in foam against the base of the cliffs more than 1000 feet below (Figs. 8, 19).

I may add a further illustration of the destructive action of the wind which can likewise be observed at the top of the Hoy cliffs. The ground is there dotted over with little pools or ponds which have been worn out of the peaty layer that forms the surface. Each of these hollows begins by some accidental depression, in which the rain collects and causes the heath or grass to decay. When the water disappears, the bare peat is dried by the wind and partly blown away. The hollow is thus deepened and widened. The next heavy rain

converts it anew into a pool, and as the wind throws the surface of the water into ripples, these, in beating upon the surrounding peat, crumble it down still more, and the shallow basin is thus continually enlarged.

Brooks and Rivers

Instead of formally describing the geological work done by running water, let me in imagination transport the reader to the long bald scalp of one of the higher hills among the pastoral uplands of the south of Scotland, and ask him to descend with me the course of a stream that we see furrowing the hillside below us. Striking across the bare moor, we reach the spring or "well-eye" whence the rivulet takes its rise—a patch of bright-green amid the brown heath, that may treacherously conceal a deep pool of water or a basin of liquid peat. Issuing from this source, the rivulet trickles at first along the heath and bent, but soon cuts through these into the black peaty layer below them, where it runs for a short distance as in a furrow or gutter. But gaining volume and force as it works its way down the steeper slope, it digs its channel through the peat into the layer below, wherein the stones are bleached white by the solvent action of the organic acids in the peat. Every yard that we descend shows us more evidence of erosion. The runnel has now cut deeply into the cover of rain-wash, drift, or decomposed stone that lies on the more solid rock below. So great is the erosion, that the stream has excavated a deep narrow gully in this superficial layer of loose material, and the coherent stratum of peat projects on either side in black cornices, which from time to time break off. Hence blocks of peat several yards in circumference lie in tumbled ruin at the bottom of the ravine, where they are eventually broken up and washed away down into the valley. The rapidity with which such a deep narrow trench may be formed on a steep hillside is sometimes strikingly exemplified by the

fate of one of the sheep-drains cut on those uplands to carry away the surface-water. Sudden heavy rains, or what the shepherds call "waterspouts," occasionally discharge such a volume of water into one of these shallow trenches that it becomes for the time the channel of a swift torrent. When the drainage has once found its way into such a channel, it is apt to keep to it. Successive rains thus dig the gully deeper and wider, until in perhaps not more than six or eight years it has become a yawning chasm 10 or 15 feet deep (Fig. 9).

FIG. 7.—Sand-dunes near Durness, Sutherland.

Examples of the unexpected rapidity with which gullies may thus be formed under favourable conditions can be gathered along many parts of the coast where rocks of no great durability descend in steep slopes upon the beach. In this respect there is perhaps no more instructive shore than that of Gamrie in Banffshire. The materials on which denudation there takes place consist of various "drifts," conglomerate, and red sandstone, all of which are comparatively easily disintegrated. In 1879, during a visit to the place, I learnt that a drain made about fifty years before that time, for leading water to a mill at Findon, had been widened and

deepened by the water itself until it had become a gully 8 or 10 feet deep and from 6 to 8 or 9 feet broad. When the water poured over into one of the natural ravines below Findon, so great was the erosion, though it took place only when the sluice was from time to time opened, that the proprietor was obliged to lead the stream away along the hill-side to another ravine; otherwise, the gully would ere long have cut its way back to the farm-house and buildings. It was the destruction caused by this mill-stream in the ravine below Findon farm that laid bare the nodular "fish-bed" which has since become so famous for its ichthyolites. The whole of this district abounds in illustrations of the power of running water in the excavation of ravines. Numerous deep gullies have been dug out of the conglomerate and red sandstone by small runnels that descend to the beach in Gamrie Bay. Still more remarkable are the numerous gashes that have been trenched in the greenish brecciated conglomerate at the Torr of Troup, south of Pennan Bay. On a small scale they recall the ravines of the Old Red Sandstone on the south side of the Highlands.

In the Western Highlands evidence has been gathered which shows the appreciable amount of change wrought by streams that are liable to heavy floods. The rivers Etive, Kinglas, and Orchy have made considerable modifications of their channels during the thirty years that have elapsed since the publication of the six-inch Ordnance maps of the region which they traverse. They have cut away extensively some parts of their alluvial terraces and have spread out fresh alluvium elsewhere. While mapping the ground at the mouth of the Etive, Mr. Kynaston has ascertained that the bank of the river along the outer side of a bend is cut away at the rate of a foot or more in the year.[1]

Returning now to the track of our typical stream, we find that, where it eventually cuts into the solid underlying rock, it has

[1] *Summary of Progress of the Geological Survey* for 1898, p. 170.

gradually hollowed out a little gully, in the bottom of which it flows. At the foot of the steep hillside, it encounters a flat meadow, and there, its current being checked and its carrying power being consequently much diminished, it drops the burden of detritus which it has swept down in its bed. These materials are spread out in fan-shape on the plain, and in more mountainous districts form a striking part of the scenery of the valleys. Conspicuous examples of such alluvial fans may be seen, for instance, in the Pass of Drumouchter, through which

FIG. 8.—Weathered sandstone, top of great cliff, Island of Hoy, Orkney.

the Highland Railway runs across the watershed of the country. There, on the flanks of the two mountains that face each other across the glen, the Sow of Athol and the Boar of Badenoch—

> "Oft both slope and hill are torn,
> Where wintry torrents down have borne,
> And heaped upon the cumbered land
> Its wreck of gravel, rocks, and sand."

I will further suppose that, after winding about in its flat valley, and being joined by similar rills from either side, our

stream, growing in volume as it advances, at last enters a thick wood, from which issues the roar of a waterfall. Skirting the wood and rejoining the stream a little farther down, where the valley somewhat contracts, we find ourselves on the brink of a deep ravine, at the bottom of which the water dashes merrily onward between precipitous walls of fern-tufted rock. The idea that naturally suggests itself in such a scene is to look upon this rent as due to some convulsion by which the solid earth has been broken open. But if that idea were true there ought to be some evidence of it in the dell itself. Yet were we to descend to the bottom and search for such evidence, we should almost certainly find the ledges of rock to be traceable unbroken across the bed of the brook. Had the ravine been a chasm produced by underground disturbance, not only would the rocks along its bottom have been fractured, but the gaping walls would have been separated, not by unbroken rock, but by dislocated masses from either side. Nevertheless, to one who has never thought of the subject, nor given heed to the operations of running water across the surface of the land, the assertion that no earthquake or convulsion has had any share in the formation of the ravine seems mere paradox, and he will incredulously ask whither he must turn to find another natural agency which, grand in its working and mighty in its results, could have opened so striking a gash in the surface of the land. Such a question reveals the true cause of the prevalent misconceptions regarding the origin of the topography of the land. Men look not at the nature of the process, but at the magnitude of the results. The completed change stands before them in all its simple grandeur, and they naturally associate this unity of effect with the operation of some single potent cause.

But if subterranean co-operation is excluded, by what process has the gorge been formed? The answer to this question is furnished by the waterfall. For the sake of simplicity, let me suppose that the ravine resembles many which may be seen

among the Old Red and Carboniferous sandstones of the Lowlands, that the strata are nearly horizontal, and that the same beds can be recognised on both sides. The ledge of stone, over which the water rushes at the edge of the fall, may be traced continuously across from side to side of the dell, thus again demonstrating that the gorge is not a mere fissure opened by some force acting from below (see Fig. 101). Behind the cascade, the face of rock is kept constantly dank and dripping, and rots away beneath the harder projecting ledge over which the water shoots. Portions of that ledge must from time to time break off, for large masses of it, some of them evidently not long dislodged, cumber the bottom of the dell. And here is the key to the history of the gorge. The waterfall is cutting its way backward, and slice after slice falls away from the front of the cliff over which it pours. The cascade, in this way, retreats up the stream. A few centuries ago it probably stood some feet or yards farther down, and a few centuries hence it will be found some way higher up. The ravine has consequently been produced, not by the opening of a fissure, but by the gradual erosion of the rocks as the waterfall has receded up the stream. The same process will continue, and the ravine will grow in length so long as the rocks present the same structure to the action of the water. But if, owing to any change in their arrangement or character, the materials over which the water leaps can be more rapidly cut away than those underneath them, then the wall behind the cascade will gradually be cut down, and instead of one shoot of water there will be a series of little falls or a line of rapids.

Much may be learnt in such a dingle regarding the action of rivers in hollowing out their channels. In not a few places, for instance, round, well-worn basins may be noticed in the rocks that form the bed of the stream. During dry summer weather, when the brooks are low, these basins or pot-holes may be easily examined. Each of them will be found to have

its bottom strewn with smooth, polished stones or gravel, and its sides will be seen to be similarly worn. The activity of the stream is at that season almost at zero, and one can hardly, perhaps, imagine how such deep, circular cavities could have been scoured out of the solid stone. But let any one visit the same scene when the stream in flood comes roaring down the rocky gorge, sweeping along its burden of mud, sand, gravel, and stones, when the boulders may be heard striking against each other as the torrent drives them forward, and when in a few hours many tons of detritus are carried down and pushed along the bottom and sides of the channel. He will then better understand what a powerful grinding mill the stream at its full flood must be, and how it can wear away its bottom and walls so as both to widen and deepen its channel. Each pot-hole marks the place of an eddy or swirl of the current, whereby stones are kept in circulation until they gradually excavate a deep round hole in the solid rock. By the union of a number of these cavities the channel of the stream is appreciably deepened. When a line of drainage has once been graven on the surface of the country, hardly anything short of what would be truly a convulsion of nature can turn the water out of it. The line sinks farther and farther into the solid framework of the land.

Continuing our course down the stream, we pass beyond the end of the gorge and enter upon an opener, flatter portion of the valley, through which the water meanders with gentler current. The surface of this meadow-like plain, or "haugh" as it is called in Scotland, is raised only a few feet above the level of the stream, and is evidently liable to inundation, for after a "spate,"[1] its surface will be found to be marked with lines of leaves, twigs, and other wreckage, which show where the margin of flood-water has stood. Every such inundation will tend slightly to raise the level of the plain by depositing sand or silt upon it, the water being, as it were, filtered when it

[1] *Spate*, the Scots word for a river-flood.

flows over the vegetation. On the other hand, the effect of floods is to scour out the bed of the stream, and consequently to lower the level of the water. By these two operations, the vertical distance between the level of the flood-plain and that of the water is continually being increased. Hence, the inundations tend to become fewer and less extensive. The limits of even the highest floods will begin to shrink, and the time will come when the water will no longer extend over any part of the flood-plain. But as the stream deepens its

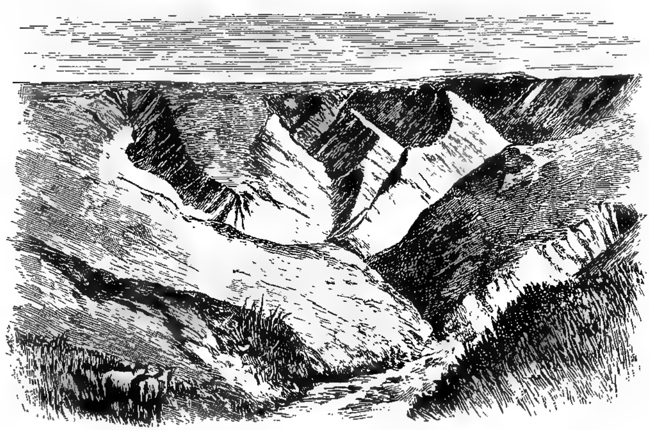

FIG. 9.—Gullies and ravines at the head of Glenkip Burn, Leadhills.

channel, it attacks its former flood-plain at the side, and cuts away slice after slice of the loose alluvial material, which it strews along its channel and its banks, so as to build up another flood-plain at a lower level. In this way it continually passes and repasses across the bottom of its valley.

That these operations have been in progress for a long time is shown by the fact that other similar, but usually narrower, strips of level meadow rise on either side high above the stream. Sometimes there are three or more such terraces, each of which marks a former flood-plain, and shows the level

at which the stream once flowed. All the large rivers of Scotland are fringed with these memorials of their history. And among the hilly regions, even the smaller streams, in eroding their channels, have left fragments of their alluvia 100 feet or more above the channels in which they now flow. As a good example of the process of terrace-building, even by a small stream, the accompanying section of a part of the course of the Water of Leith in Midlothian is here given (Fig. 10). The valley is one of pre-glacial date, for it is filled with boulder-clay, in which the present stream has eroded its channel. The oldest terrace runs from 20 to 30 feet below the top of the bank. From 4 to 6 feet below it lies a second terrace, and underneath this at a vertical distance of 3 to 4 feet is the flood-plain which is now from time to time overspread by the Water of Leith during spate.

Though the mechanical work of running water chiefly merits attention for its effects in land-sculpture, we are sometimes reminded that the chemical solvent action of the water is also not without influence. Where, for instance, a stream issues from a peaty region charged with the organic acids which the peat supplies, it produces considerable corrosive effect upon limestone or other calcareous rock over which it flows. As an illustration, reference may be made to the little stream which, in descending from the peat-bogs into the head of the Kyle of Durness, flows for some distance in limestone, and has eaten away the base of the low cliffs on either side (Fig. 11).

Before quitting the subject of river-action I would refer to the magnitude of the effects of a single great rain-storm, as illustrated by one of the most memorable examples ever experienced in Scotland—the famous Morayshire floods of the year 1829. There had been a season of unusually hot weather during the summer, and this was followed in the first week of August by such a downpour of rain as does not seem ever to have been equalled within historic times. The sudden-

ness with which the waters rose, the great size the streams attained, and the unusual length of time that the spate endured, combined to work an altogether unprecedented amount of havoc in all the rivers descending from the northern flank of the Grampians through the counties of Nairn, Moray, and Banff. In some of the narrow gorges, the streams rose 40 or 50 feet above their normal level, and such was the force with which the swollen waters rushed along, that well-built stone bridges were swept away, sometimes in one solid mass that shot down the flood for some yards before it went to pieces. Hundreds of acres of fertile land were torn up, and their soil was carried to the sea. Banks of clay 40 feet

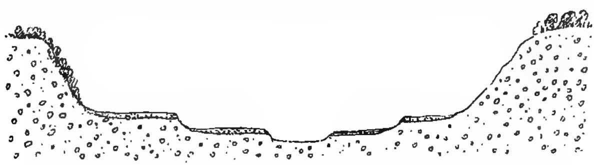

FIG. 10.—Alluvial terraces of the Water of Leith, cut out of boulder-clay, at Leith Head Mill.

or more in height were cut into, and huge slices of them sank into the rivers and were soon demolished. Altogether a greater amount of havoc was probably wrought in those three days than has been done by the same streams during all the years that have since elapsed.[1]

It will be seen that in using rivers as one of her sculpture tools, Nature produces two distinct kinds of effects with them. On the one hand, she carves out their channels, graving these more and more deeply upon the surface of the land, so that when once traced out they are hardly ever effaceable, save by some exceptional catastrophe that disrupts or buries the surface of the land, and entirely changes the lines of drainage. On the

[1] For a graphic account of this great disaster to the north of Scotland, see Sir Thomas Dick Lauder's *Account of the Great Floods of August 1829 in the Province of Moray and Adjoining Districts.* 1830.

other hand, she makes use of rivers as instruments for removing the detritus which, in the course of her carving operations, she produces over the surface of the land, whether by the rivers themselves or by other sub-aërial agencies. The sediment thus carried away is borne along as far as the carrying power of the streams will permit. Whatever checks the rate of flow of the water diminishes its capacity for transport, and causes it to let more or less of its sediment sink to the bottom. This check of flow and deposit of sediment take place at any sudden lessening of the angle of slope of the channel, as has been already illustrated; and also at the junction of one body of water with another which has a less rate of motion, or is practically at rest. In the latter case, we see the result in the deltas that are pushed out into a lake from the mouths of its tributary streams, and in those that are gradually filling up the higher parts of estuaries. Many admirable instances of such lacustrine and marine deltas are to be seen in Scotland. There is, indeed, hardly a lake in the country where illustrations may not be gathered of almost every stage in the process of infilling, until the various deltas meet and the lake is finally silted up. One of the most noticeable operations of running water in the country is this gradual effacement of the lakes, which, though still numerous enough, were once so profusely scattered across the surface. The process is obviously a comparatively rapid one; at least, from a geological point of view, no vast period can have elapsed since the lakes began to be silted up. If the rate at which the process takes place were ascertained, some estimate could be formed of the time within which any given lake will have disappeared; and if an approximate measurement could be made of the amount of sediment already laid down in the lake, we might be furnished with a means of calculating how long a time has passed away since the lake came into existence. As most of our lakes took their origin in the Glacial Period, the determination of their antiquity would help to fix the date of that period.

Of the shallowing of sea-inlets by the discharge of rivers, numerous Scottish illustrations may likewise be cited. They are most observable on the east side of the country. The upper reaches of the Firths of Forth and Tay display thick deposits of alluvial mud and sand, which at low water are seen to cover wide tracts of ground. The northern fjords likewise supply excellent examples, particularly the Beauly, Cromarty, and Dornoch Firths, and the Kyles of Tongue and Durness. On the west side of the country also, conspicuous illustrations

FIG. 11.—Chemical action of a stream on limestone, Durness, Sutherland.

may be observed at the head of each of the sea-lochs which indent the coast-line. The sides of the fjord are prolonged inland to form the sides of the glen, and the bottom of the glen was obviously in many cases once occupied by the sea. The alluvial plain is gradually advancing into the shallowing salt water. These marine accumulations, which will properly come for consideration in the next chapter, are almost entirely due to the deposit of the detritus swept down from the Highland mountains by the streams, whose united waters are carried out to sea in the estuaries. Loch Carron may be cited as an excellent example of these features.

In considering the operations of any one of the superficial agents that are busy modifying the surface of the land, we must remember that the ultimate result achieved may be greatly modified by two potent factors—geological structure and the concomitant working of some other agents which likewise affect the terrestrial surface. How geological structure comes into the question will be best explained in later parts of this volume from actual examples of its local influence. The co-operation of the different disintegrating and denuding forces upon the land is governed in great measure by varying conditions of climate. Where, for instance, the mean annual temperature falls below 32° Fahr., frost, snow, and ice take their place as powerful agents in land-sculpture. Where the climate is dry, the disintegrating effects of saturation and desiccation are eliminated, and the general surface of the land is exposed only to such influences as great and rapid alternations of temperature. In such cases, rivers that are copiously fed from mountains beyond or above the arid plains are allowed to exert their own peculiar modes of land-sculpture with the least interference from other agents. On the other hand, where the climate, if not humid, is at least characterised by an average rainfall and by warm summers and somewhat severe winters, the general waste of the surface of the land probably reaches its maximum, and the rivers are then not permitted to exercise their functions without constant modification. A river can only act upon the rocks over which it flows. Hence when it is allowed to work with its utmost power and speed, its maximum effect is seen in the excavation of a long deep ravine. On the arid plains of Utah and Arizona, for instance, the Colorado river and its tributaries have eroded lines of cañon hundreds of miles long, and in some places more than 6000 feet deep. But where the banks of a river-channel are attacked by vigorous atmospheric disintegration, they are not allowed to grow into vertical walls. On the contrary, they are rotted by rain, splintered by frosts, loosened

by springs, and wasted by wind and sun, so that they crumble down, and the rubbish that descends from them is swept away by the stream below. They become sloping declivities, steeper or gentler according to the structure of the rocks and the vigour of the sub-aërial denudation. Hence in such a climate as that of Britain, valleys with gently-sloping sides ought to be, as in fact they are, the general rule; and narrow precipitous ravines, where the activity of the streams has been much greater than that of the other atmospheric agents, ought to be exceptional. Such ravines, where they occur, are probably always to be explained by some local peculiarity of structure in the rocks, or some specially favourable form of surface over which the streams began to flow when the land last emerged from the sea or from its cover of snow and ice.

A remarkable feature in river scenery is the frequent occurrence of a gorge immediately below a wide expansion of the valley. This association is well illustrated in Scotland, and will be further described in Chapter VIII.

Springs

That portion of rain which, instead of flowing off at once in brooks and rivers, sinks under ground, and after a subterranean journey of greater or less length, reappears at the surface in springs, is employed by Nature as a characteristic implement in fashioning the contours of the land. Its effects are twofold: on the one hand, the water acts chemically, and dissolves the rocks through which it flows; on the other hand, it acts mechanically, saturating rock-masses, lubricating the surfaces of their internal joints and fissures, removing their finer particles, and thus greatly aiding in their superficial disruption.

The solvent action of subterranean water is best seen in districts of calcareous rocks. As already remarked, the outcrop of a limestone can often be traced across a moor by a line of

curious depressions of the surface. These "swallow-holes," or "sinks," to which allusion has been made (Fig. 2), have been dissolved out of the limestone by percolating water, and the peat or soil gradually sinks into them. Not infrequently they communicate with subterranean passages and tunnels, which have, in like manner, been eaten out of the rock by the solvent action of water. Sometimes these cavities expand into spacious caverns, which, where they open upon a plain or slope, served in old times as dens for wild beasts and sometimes as habitations for man. Owing to the comparative infrequency of limestone or highly calcareous rocks in Scotland, examples of such caverns and labyrinthine underground passages are much less common and extensive than in England, where the Carboniferous and Devonian limestones have been hollowed out on a large scale, and possess many famous caves. One of the most honeycombed tracts I have met with in Scotland is that occupied by the calcareous Jurassic sandstones of the Inner Hebrides. The east side of the Island of Raasay presents a lofty cliff of these sandstones, at the summit of which lies a bare moor. Innumerable swallow-holes open along this moor, sometimes so treacherously concealed with long grass and fern that in a mist or in the dark a traveller might easily be lost in them. Prince Charlie's Cave, near Portree, and the Spar Cave of Strathaird are well-known examples of caverns in the same group of rocks.

Occasionally the water of springs deposits at the surface the mineral matter which it has abstracted in its underground journey. Such is the origin of the brown ochry scum of iron-oxide that gathers upon the stones and grass washed by the outflow from a chalybeate spring. Such, too, is the white crust of carbonate of lime which hardens round the objects that lie in the pathway of one of the so-called "petrifying springs" of calcareous districts. In some places, the material thus removed and deposited accumulates in masses that are large enough to form a distinct feature in the landscape. But

nothing of that magnitude is to be found in Scotland. The deposit of white travertine from calcareous springs takes place there only on a small scale, as at the well-known Starley Burn, on the coast of Fife, between Aberdour and Burntisland.

Of far more importance in the general sculpture of the land, when the rocks, as in Scotland, are not generally calcareous, is the mechanical action of underground water. Filtering through the interstices and joints of rocks, loosening the cohesion of particles and removing them, and above all lubricating the divisional surfaces and enabling these, in favourable positions, to slide over each other, underground water tells powerfully in breaking up the rocks of steep banks and precipices. The most striking Scottish examples of this process are furnished by the cliffs of boulder-clay so abundant along the stream-courses of the lower grounds. After wet weather, large semicircular portions of these "scaurs" may be seen to have slipt half-way down, carrying with them on their tops portions of the meadow above. Their lower slopes reveal the cause of dislodgment, in the streams of pasty mud that ooze out towards the water-course. Such landslips are continually occurring, where the disrupted material, instead of being allowed to accumulate as a protection against the face of the cliff, is broken up by the weather and swept away by the stream. Hence, in spite of the efforts of Nature to heal the wounds with a covering of vegetation, fresh raw scars constantly arise.

Similar landslips in boulder-clay may be seen along the sea-margin at various parts of the coast-line of Scotland. The cliffs at Rosemarkie supply good examples of them. Not infrequently they are separated from the present shore-line by a platform of raised beach, and owe their origin, not to the action of the waves, but entirely to that of springs. In such circumstances every stage may be observed, from the fresh scar of last winter to examples so ancient and so grass-grown as not to be readily recognised. The inner margin of the old marine terrace north of Ballantrae, on the coast of Ayrshire, affords

excellent illustrations of such a series. In short, all over the Lowlands, where streams have hollowed out their channels upon a platform of boulder-clay, the same features meet the eye.

Among solid rocks similar effects may sometimes be seen, though the rate of degradation is there much slower. Where a thick stratum of pervious stone lies upon another of more impervious kind—a massive sandstone upon shale or clay, for example—and where these rocks end off in a cliff or steep bank, the conditions are favourable for the occurrence of landslips. Water oozing out along the outcrop of the lower bed loosens the support of the overlying stratum, which, consequently, from time to time breaks off in large blocks that roll down to join the masses that have already fallen. In this way, the vertical edge of a harder bed forms an escarpment, which, by continual loss along its face, creeps backward. Many admirable examples of this striking element in the topography of the Lowlands are supplied by the great dolerite sills, such as those of the Lomond Hills of Fife. Still more gigantic landslips have occurred in the Jurassic rocks of Skye and Raasay.

Frost

In close connection with the disintegrating effects of springs on cliffs and steep slopes of rock, comes the influence of frost. When the water, which is trickling between the joints of a cliff, is frozen, it expands, and in so doing exerts a vast disparting force on the rocks within which it is confined. On the thawing of the ice, the rocks which have been thus separated do not return to their former position; the severance remains until it is increased by another frost. Winter after winter, as the loosened masses are separated, the wedge of ice is driven farther in between them, and at last, losing cohesion and support, those on the outside fall with a crash from the face of the cliff, leaving a raw scar to mark whence they have come.

Every mountain-group in Scotland will be found to supply

FIG. 12.—Pinnacles of granite, crest of cliffs, Lochnagar, Aberdeenshire.

examples of this operation. Some rocks, being more jointed or opening more easily along their joints than others, are more readily broken up by frost. Granite, for instance, is remarkable for the perfection of its jointing and also generally for its toughness. It may crumble away on the surface, but otherwise may remain coherent and durable, though there are some varieties that decay far down into their mass. Its numerous joints, however, afford admirable scope for the action of frost. On lofty mountain crests, accordingly, granite frequently presents a most impressive array of splintered crags. Pinnacles, "aiguilles," and buttresses of the most varied forms and dimensions rise along the face of the precipices. Vast rifts, descending for several hundred feet, show where the joints have most easily opened, and naked vertical walls mark where the ice-wedges, driven home by the winters of centuries, have at last detached huge slices from the face of the cliffs. The tourist who has climbed Lochnagar will well remember the grim precipice that yawns beneath him as he gains the crest of the mountain and looks northward to the valley of the Dee (Fig. 12). There, screened from the sun, the snow lingers long into the summer, and frost finds a congenial home. Inch by inch the vertical joints are being opened farther into the face of the cliff. Along the edge one can, as it were, watch all the stages of the process, from the fine rift just starting like a crack in a window pane, up to the loosened pillar which now stands gaunt and alone in front, and awaits the fate that is eventually to hurl it into the gulf below. Far down, between the base of the precipice and the little tarn that lies gleaming in the shadow of the mountain, we can see the grey slopes cumbered with debris, and can hardly believe, so much does height deceive us, that these long slopes are not mere trails of sand but avalanches of blocks, many of them hundreds of tons in weight, which, in the course of ages, have been wedged off from the cliffs, and are now travelling slowly to the plains, still, however, a prey to frost and rain, sun and storm, and

gradually breaking up into fragments and sand as they descend (Fig. 54).

Besides splitting solid rocks into separate blocks, frost disintegrates their surface, as the water contained between their particles freezes. This result, especially observable in tracts where there is abundant moisture in summer and great cold in winter, is familiarly seen in the pulverising of soil. Every one knows that when thaw comes after a long black frost, the country roads are often in as bad condition as after long rain, the reason being that the frost, having separated the particles of earth, has allowed the thawed moisture to mix thoroughly with them. Hence the value of a hard frost upon bare ploughed land. The soil is, as it were, ground down finer, new portions are added to it from the surface of stones which it may contain, and fresh mineral matter is thus provided for the rootlets of plants.

CHAPTER III

THE SEA AND ITS WORK ON THE SCOTTISH COAST-LINE

In contemplating the gradual waste to which the surface of the earth is everywhere subjected, the observer is soon struck with the signal proofs of decay furnished by that outer border of the land which is washed by the sea. The abrupt cliffs that shoot up from high-water mark, the skerries that rise among the breakers a little way from the shore, and the sunken reefs that lie still farther out to sea—all tell of the removal of masses of solid rock. A little reflection leads us to perceive that the abrading power of the sea must be almost wholly confined to that upper part of the water which is affected by winds and tides, and that in deeper portions there is probably on the whole no sensible erosion of hard rock, though currents may here and there be capable of moving gravel and stones so as to cause a certain amount of attrition.

The waste which takes place along the line where land and sea meet has a twofold character. In the first place, there is a direct abrasion by the sea itself, and it is this loss which is now to be considered. But, in the second place, cliffs and precipitous banks overlooking the waves are subject to that never-ceasing atmospheric waste described in the last chapter. In many places, indeed, the sea does little more than remove from tide-mark the debris which has fallen from the cliffs owing to the operations of springs and frosts. Thus sea-cliffs, like the walls of river-gorges, may receive no permanent

protection from an accumulation of their own ruins in front of them. In looking at the results of the wear and tear of a coast-line, we are apt to assign, perhaps, too much importance to the action of the breakers, and too little to the less obtrusive but more constant influences of rains, springs, and frosts. It may be impossible to give to each agency its due share in the wasting of the shore, but it should not be forgotten that in what is usually called marine denudation the atmospheric influences play a great part.

Some indication of the relative potency of the sea and sub-aërial agents is afforded by the forms of sea-cliffs. The sea only wears away the base of a precipice, but air, rain, springs, and frost attack every accessible part of it. Hence, other things being equal, where a cliff is so eaten away below as to overhang, it not improbably points to greater rapidity of breaker-action. Where, on the other hand, the cliff recedes towards the top, it proves that its upper portion has been more worn away by sub-aërial disintegration than its lower part has been by the sea; and as overhanging cliffs are quite exceptional, it follows that in the demolition of a cliff, and the constant advance of the sea landwards across a plain of erosion, sub-aërial disintegration really takes, as a rule, a larger share than the waves and currents of the sea.

In the production of coast-cliffs, the structure of the rocks plays an important part, especially by the way in which these masses are split along their lines of joint. It occasionally happens that a rock breaks away along clean-cut joints which, when vertical, leave smooth perpendicular walls of rock. These joints are opened from above by the atmospheric agents, and slice after slice is cut away from the precipices, which are thus enabled to retain their wall-like character. Nowhere in Britain can these features be so impressively seen as along the great ranges of Old Red Sandstone coast-cliffs in Caithness and the Orkney Islands (Figs. 13, 14, 17, 18, and 19). When the joints are inclined away from the sea the cliffs actually

overhang; but this is obviously not due to any greater demolition of their base by the waves. The true explanation will be at once understood from Fig. 14, which represents the overhanging cliffs in one of the Orkney Islands (compare also the view of the coast-line near Wick, Fig. 17, and of the Noss Head, Shetland, Fig. 20).

No one can watch the progress of a storm on an exposed rocky coast without being strongly impressed with the powerful effects of breakers in wearing away the margin of the land.

FIG. 13.—Flagstone cliffs, Holburn Head, Caithness.

A wave which can deal a blow equal to a pressure of 6083 pounds, or nearly three tons, on the square foot (and this is the ascertained impetus of storm-waves among the Outer Hebrides), is no feeble instrument of abrasion. Yet such a wave appears to have of itself little or no power to grind down the surface of the rocks on which it beats, for that surface, even after a storm, is found to be just as plentifully coated with living barnacles as before. If the friction of the water could rub down the stone, these cirripedes would be removed first.

Only where by its enormous weight and impetus it can break off a loosened mass of rock, may a wave be said to act by its own sheer force.

In the great majority of cases, however, breaker-action eats into a coast-line either by battering down the rocks with their own debris, or by enlisting the co-operation of the air. A wave that lifts up and sweeps forward gravel, boulders, and even large blocks of stone, is a far more formidable instru-

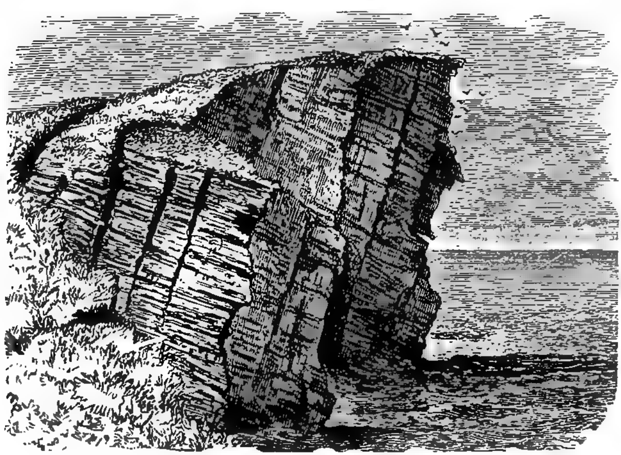

FIG. 14.—Flagstone cliffs, Brough of Birsa, Orkney.

ment of destruction than even a larger wave which is not armed with the same weapons. The stones that are thus swung on by the tempest fall with prodigious force against the rocks of the shore; brought back by the recoil of the wave, they are caught up again by its successor and once more hurled forwards upon the rocks. After a storm the lower parts of an exposed sea-cliff may be seen to be covered with bruises, each of which marks the effect of a blow dealt by one of the pebbles or boulders of the shore shingle. These loose stones are also themselves similarly bruised or marked by

"bulbs of percussion," sometimes even broken into fragments, which in turn are worn down, rounded, smoothed, and polished by continued agitation of the water. And thus, by what has been aptly termed a kind of sea-artillery, even the hardest rocks of an iron-bound shore are worn away.

Again, a huge billow, falling on a cliff that is penetrated by many cracks and passages, drives the air into these with prodigious force. The consequent contraction and expansion of the air must needs act with great effect in widening clefts and helping to disrupt rocks. The hydraulic pressure of large waves which fall upon cliffs with a force equivalent to a pressure of three tons on the square foot, cannot but tend also to dislodge masses of solid rock.

To see the character and effects of sea-action, the observer should betake himself to some rocky shore on which falls the full roll of the Atlantic. He will there find, if the coast be a precipitous one, that the rocks above the reach of the waves are rough and ragged, showing everywhere traces of that sub-aërial waste which, acting along their joints, has slowly shattered the crags and sent down huge blocks to the beach below. There the fallen ruin, coming within reach of the waves, is turned into a further means of augmenting the destruction of the cliffs. Ground down by the waves into well-worn boulders, it is driven up against the cliffs, which along their base are smoothed and polished like the shingle. The line between the rough surface overhead, marking the progress of the atmospheric waste, and the well-worn zone of the beach, pointing to the work of the sea, is often singularly sharp. But the base of the cliff is not merely polished by the friction of the boulders; it is in many places hollowed out into overhanging recesses, clefts, and caves. At the farther end of one of these excavations may be seen the rounded boulders that are carrying on the work of demolition, likewise the passage which, worked by the compressed air through the roof, has been subsequently enlarged by many a storm, until now, when a

gale sets in strongly from the sea and sweeps the breakers at high water against the cliffs, the yeasty sea-water is shot up through the opening high into the air, with a noise like the firing of a cannon. Many such "blow-holes" or spouting holes may be seen along the Scottish coast-line. One of the best known is the Buller of Buchan, in Aberdeenshire (Fig. 15). In this case, as frequently happens, the upper part of the

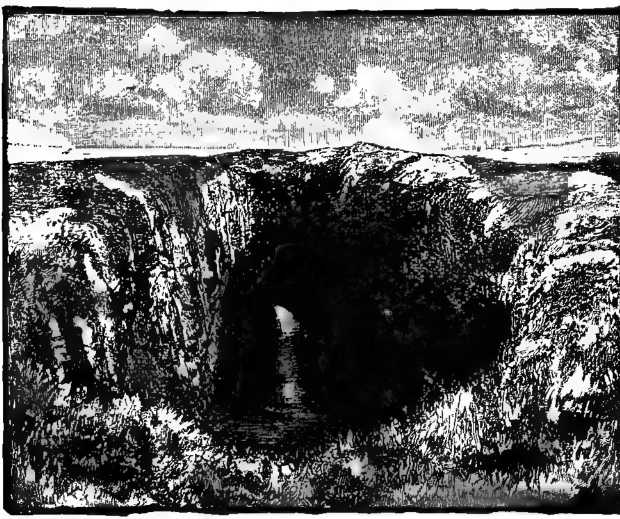

FIG. 15.—View of the Buller of Buchan from the land side.

opening or roof of the sea-cave has fallen in; so that, from the level moor or field above, one advances to the top of a huge cauldron, at the bottom of which the chafing tides may be seen. But no one who knows such places in calm weather only can realise their tumult and grandeur at the height of a great storm.

On a rocky coast, between the upper limit of the tide and low-water mark, crags and skerries may be noted in every stage of decay. Here rises an out-jutting part of the cliff which

has been separated, while the breakers meet and burst into foam in the narrow passage. Yonder a mass, once evidently connected with the main cliff in the same way, has been sundered by the roof of the tunnel falling in, and it now stands up as a tall, massive outwork of the line of rampart behind (Figs. 17, 18, and 19). Lower on the narrow beach, worn, tangle-covered bosses of rock rise above the shingle and boulders, and run out to sea in low reefs, usually fringed with foam even in the calmest day, but mounting in places into islets haunted by seal and wild-fowl. Everywhere the eye rests upon proofs of unceasing destruction. We see that the cliffs must once have stretched seaward, at least as far as yonder sea-stack, fully a furlong from their present limit, and how much farther no man can tell. We are here impressively taught that the selvage of land which has been cut off has been carried away by the sea. The whole process in all its stages is manifest before our eyes. We note how the weather wastes the cliffs above, and how the sea batters them below. It is impossible to doubt that if, in a comparatively short geological period, a strip of land, say a furlong broad, has in this way been planed down, there is here revealed to us a power of waste, the effects of which, if unchecked from any other cause, can have no limit short of the total demolition of the dry land.

In looking more narrowly at the progress of this abrasion, we find it dependent not merely on the prevalent winds and the consequent *fetch* of the breakers, but in large measure upon the varying geological structure of the coast-line. Expressed in the simplest form, the relation of this structure to marine erosion is the same as in the general sub-aërial degradation of the interior of a country, and may be stated thus: Hard rocks present most resistance to the inroads of the sea, and consequently tend to project as headlands; soft rocks are more easily demolished, and, therefore, recede before the waves into creeks and bays. The waste of the eastern shores of the British Isles is more rapid than that of the western, because

though the waves of the North Sea are less powerful than those of the Atlantic, yet the rocks forming the coast-line on that side are, as a whole, more easily worn away than those on the west side. If the soft sandstones and shales, clays, and sands of the eastern sea-board were open to the full fury of the western ocean, there would be a sad yearly tale of loss and ruin. Perhaps it may be objected that the western coast is far more indented with inlets than the eastern, and therefore shows more strikingly the destructive powers of the sea. But these firths and sea-lochs, as will be afterwards pointed out, are not the work of the sea; they are, in truth, submerged land-valleys, and point to the prolonged action of sub-aërial waste, when our islands stood some hundreds of feet above their present level and were probably joined to the mainland of Europe.

There can be no doubt that, impressed by the obvious potency of the waves along an exposed coast-line, geologists were formerly disposed, especially in Britain and Western Europe, to attribute to the sea an exaggerated importance in the general denudation of the land. This tendency has now been moderated. There is a general agreement that sub-aërial denudation is so much more widespread and constant, that long before the land could lose more than a mere marginal strip by the action of the sea, it would be reduced to a base-level of erosion near sea-level by the operation of the atmospheric forces. Nevertheless it is desirable, on the other hand, not to underrate what the sea actually performs. Hence in any account of the sculpture of a sea-washed country, a prominent place may be naturally expected to be given to the work of the waves. The present chapter is meant to supply this desideratum in the case of Scotland.

It would be interesting if we could trace the gradual retreat of the Scottish coast-line since man became an inhabitant of the country, or even since the time to which the earliest historical notices refer. No sufficiently definite written

records of such changes, however, go farther back than, at the most, three or four hundred years. There are, indeed, traditions of land having once existed, where for many a century have rolled the waves of the salt sea; just as in Cornwall there still survives the memory of a district, called the Lionesse, now covered by the Atlantic, but which in the days of the Knights of the Round Table is said to have been rich and fertile. But such traditions are too vague to be, at least in the meantime, of any geological service. It is with the time of written history, therefore, that we must deal. Though this period is short, yet it furnishes us with some instructive lessons as to the progress of marine erosion. Let me conduct the reader in an imaginary voyage round the sea-margin of Scotland, and while the breeze drives us merrily onward he may be interested to listen to some tales of the wild havoc that has been wrought on the shores, during the last few generations, by the same sea whose waves are now leaping and laughing around us.

From the mouth of the Tweed we set sail northwards, and skirt the abrupt rocky coast which forms the sea-board of Berwickshire. The cliffs for many miles are steep or vertical, rising, near St. Abb's Head, to a height of 500 feet above the waves,—the highest sea-cliffs on the eastern sea-board of Britain,—and here and there interrupted by narrow bays and coves, which have in several instances been selected as the sites of fishing villages and hamlets. We see from the wasted and worn look of these cliffs what a sore battle they have had to fight with the ocean. Craggy rocks, isolated stacks, and sunken skerries, that once formed part of the line of cliff, are now enveloped by the restless waves. Long twilight caves, haunted by otters and sea-mews and flocks of rock-pigeons, have been hollowed out of the flat Carboniferous sandstones and the contorted Silurian greywacke (Fig. 16), and are daily filled by the tides. In storms, the whole of these vast precipices, from base to summit, is buried in foam—the

pebbles and boulders, even on the sheltered beaches, are rolled back by the recoil of the breakers, and hurled forward again, with almost the force and noise of heavy cannon. But a line of abrupt hard rock presents such formidable obstacles to the advance of the sea that the rate of waste must here be comparatively slow. Passing onward beyond these dark cliffs, with their occasional sandy creeks and green bays, we round the headland of St. Abb's, and observe that it stands there, at once a bulwark against the waves and a mark of their

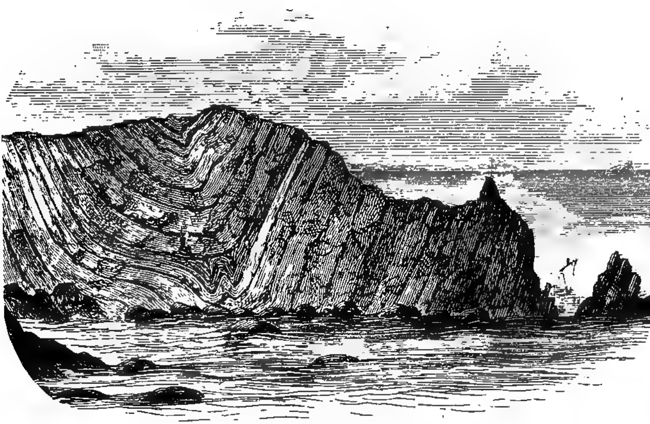

Fig. 16.—Part of the sea-cliffs of Berwickshire—curved Silurian rocks.

advance; for, being a mass of hard volcanic material, it has been able in some measure to withstand the assaults of the ocean which have worn away the greywacke and shales around it. Sweeping across the Bay of Dunglass, we observe that the cliffs at once become less lofty and irregular where the curved Silurian rocks are replaced by the Old Red and Carboniferous sandstones, and we remember with interest, as we pass the Siccar Point, that it was the unconformable junction of the younger with the older formation there displayed that formed the object of Hutton's famous visit and Playfair's

classic description. We pass the sandstone cliffs of Cove (where the old fishermen used to point to great inroads by the sea during their lifetime), and then the shores of Skateraw, where, in the early part of this century, stood the ruins of an old chapel, which were swept away many years ago, the tides now ebbing and flowing over their site.[1] Farther west stands the castle of Dunbar, at the entrance of the Firth of Forth. There the proofs of degradation and decay come before us with a melancholy reality. The old castle, once so formidable a stronghold, is almost gone—two tall fragments of wall and some pieces of masonry at a lower level being all that is left. The rains and frosts of many a dreary winter have broken down the ramparts, and the hand of man, more wanton and unmerciful in its destruction than the hand of time, has quarried the stones and blasted the rocks in the excavation of the harbour. But the sea has all the while been ceaselessly at work wearing away the very headland on which the ruin is perched. The time will come, at no very distant date, when the *Dun* or hill, from which the castle takes its name, will have disappeared, and its site will be marked only by a chain of rocky skerries. A little to the west of the castle, a huge mass of the sandstone cliffs, undermined by the sea, fell during the night some forty years ago. The scar is yet visible, though the pile of ruin at the foot of the precipice is being broken up and carried away by the waves.

It might have been supposed that the comparatively sheltered estuary of the Forth would be free from any marked abrasion by the sea, yet such is there the force of the waves that even as far up as Granton, near Edinburgh, during a gale from the north-east, stones weighing a ton or more have been known to be torn out of a wall and rolled to a distance of 30 feet.[2] Hence, within the last few generations, the sea has made en-

[1] *Popular Philosophy, or the Book of Nature laid open upon Christian Principles*, Dunbar, 1826, vol. ii. p. 160.

[2] Thomas Stevenson, *Trans. Royal Soc. Edin.* xvi. 27.

croachments, sometimes to a considerable extent, along the whole coast of the firth, even as far up as Stirling. Tracing the southern shores in a westerly direction from Dunbar, we find that they are for the most part fringed by a strip of the 25-feet raised beach, the loose sandy and gravelly materials of which offer but a feeble resistance to the encroachments of the sea. The low sandy tracts at the mouth of the Tyne, and again from North Berwick to Aberlady, have suffered loss in several places. Farther on, near Musselburgh, there was a tract of land on which the Dukes of Albany and York used to play at golf in former days, but which is now almost entirely swept away. The coast of Edinburghshire has in like manner lost many acres of land. Maitland, for instance, in his *History of Edinburgh*, describes the ravages of the sea between Musselburgh and Leith, which had caused the "public road to be removed farther into the country, and the land now being violently assaulted by the sea on the eastern and northern sides, all must give way to its rage, and the links of South Leith, probably in less than half a century, will be swallowed up."[1] The road alluded to has had to be removed again and again since this passage was written. Mr. Robert Stevenson[2] remarked in 1816, that even the new baths, erected but a few years before at a considerable distance from the high-water mark, had then barely the breadth of the highway between them and the sea, which had overthrown the bulwark or fence in front of those buildings, and was then acting on the road itself. Maitland speaks also of a large tract of land on both sides of the port of Leith, which has been destroyed. Nor are the inroads of the sea less marked as we continue our westward progress. The old links of Newhaven have disappeared. If the calculations of Maitland may be believed,[3] three-fourths of

[1] *History of Edinburgh* (published in 1753), p. 499.

[2] In an excellent paper on the Bed of the German Ocean, in the second volume of the *Wernerian Society's Memoirs*, to which I have been greatly indebted in collecting the statistics given in this chapter.

[3] *History of Edinburgh*, p. 500.

that flat sandy tract were swallowed up in the twenty-two years preceding 1595. Even in the early part of the present century, it was in the recollection of some old fishermen then alive, that there stretched along the shore, in front of the grounds of Anchorfield, an extensive piece of links on which they used to dry their nets, but which had then been entirely washed away. The direct road between Leith and Newhaven used to pass along the shore to the north of Leith Fort, but it has long been demolished, and the road has been carried inland by a circuitous route.[1] Until the waste was checked by the numerous bulwarks and piers which have been erected along the coast, the waves, having cut away the terrace of the raised beach, broke at high tide upon the low cliff of stiff blue till or boulder-clay which formed the inner margin of that terrace, as it still does in many places on both sides of the firth. The bluff of clay, once stripped of its protecting grassy cover, yielded so readily to the combined influences of the weather and the waves, that large slices of the coast-line were from time to time precipitated to the beach. A footpath ran along the top of the bank overhanging high-water mark, and portions of it were constantly removed on the landslips of clay. By this means, as the ground sloped upwards from the sea, the cliff was always becoming higher with every successive excavation of its sea-front. The risk to foot-passengers was thus great; so many accidents, indeed, occurred there, that the locality was long known in the neighbourhood as the *Man-Trap*. More than a quarter of a century ago this dangerous piece of cliff disappeared; not, however, by the destructive force of the waves, but under the combined operations of mattock, wheel-barrow, and waggon. A branch railway was carried along the coast-line, the accumulated rubbish from some long cuttings through boulder-clay was shot over the sea-cliff, completely covering it up, and thus carrying the land out to sea again. The large piece of ground thus reclaimed has been strongly

[1] Stevenson, *Mem. Wer. Soc.* vol. ii.

protected by a bulwark, which, however, has to be continually watched and kept in repair.

Higher up the Firth of Forth, at the Bay of Barnbougle, a lawn of considerable extent, once intervening between the old castle and the sea, has been demolished. Even in the upper reaches of the estuary, above the narrow strait at the Ferries, where the Forth Bridge now crosses, the waves have removed a considerable tract of land which once lay between the sea and the present road leading westward from Queensferry. Similar effects have likewise been produced on the northern shores at Culross and eastwards by St. David's, Burntisland,[1] Kirkcaldy, Dysart, Elie, Anstruther, and Crail, to Fife Ness. The seaports along this coast have all suffered more or less from encroachments of the sea—roads, fences, gardens, fields, piers, and dwelling-houses having been from time to time carried away. The reality and rapidity of the loss of land are impressively displayed by the projecting cornices of soil and turf which overhang the beach and continually break off and fall upon the sand and shingle below. From Elie to Anstruther many examples of this destruction may be seen. At St. Monan's so great has been its progress that, within the memory of men still living, the grass-covered undulating land stretched seaward over the reefs and skerries which are now surrounded or submerged by the sea at high water.[2]

[1] "At the east end of the town of Burntisland the sea comes now far in upon the land; some persons in the town, who died not long since, did remember the grassy links reach to the Black Craigs, near a mile into the sea now."—Sibbald's *Fife and Kinross* (1710), p. 62. The waste still continues, in spite of the strong railway embankment, much damage being done by occasional storms.

[2] In March 1900 I was informed by David Latto, an old whaler and fisherman, aged 82, that in his younger days he had often driven a horse and cart over these grassy knolls. I learned from him also that the roof of the rock-shelter or cave said to have been tenanted by the saint or priest who kept the shrine dedicated to the Celtic Saint Monan, fell in during the time of my informant's grandfather, rather more than a century ago. But this was due to sub-aërial decay, and not to the action of the sea, for the cave in the basalt crag stands above high-water mark.

In the parish of Crail some slender remains of a priory existed down to the year 1803. These, along with the old gardens and fences, are now wholly removed; but the adjoining grounds still retain the name of the croftlands of the priory. At St. Andrews, Cardinal Beaton's castle is said to have been originally some distance from the sea, but it now overhangs the beach. Part of the enclosing wall on the east side is now gone, together with the portion of the cliff on which it stood. A strong mass of masonry has been built up the face of the precipice to prevent further encroachment, but unless this protection is continually kept in repair, the castle must ere long fall a prey to the waves.[1]

Passing northwards along the eastern coast of Scotland, we find that the sea has encroached to a marked extent on the sands of Barry, on the northern side of the Firth of Tay. The lighthouses which were formerly erected at the southern extremity of Button Ness have been from time to time removed about a mile and a quarter farther northward, on account of the shifting and wasting of these sandy shores. The spot on which the outer lighthouse stood early in the seventeenth century, was found to be in 1816 two or three fathoms under water, and at least three-quarters of a mile within floodmark.

If the waves can bring about such important changes, even when rolling into more or less sheltered estuaries, we may

[1] R. Stevenson, *op. cit.* "The learned Mr. George Martine (*Reliquiæ Sancti Andreæ*, chap. ii. p. 3) relates it as a tradition received that the ancient Culdees, Regulus and his companions, had a cell dedicated to the Blessed Virgin about a bow flight to the east of the shoar of St. Andrews, a little without the end of the peer (now in the sea), upon a rock called at this day Our Lady's Craig: the rock is well known, and seen every day at low water. The Culdees thereafter, upon the sea's encroaching, built another house where the house of the Kirkheugh now stands, called Sancta Maria de rupe, with St. Rule's Chapel, and says in his time there lived people in St. Andrews who remembered to have seen men play at bowls upon the east and north sides of the castle of St. Andrews, which now the sea covereth at every tide."—Sibbald's *Fife and Kinross*, p. 152.

expect that their power will be found still greater where, without any bounding land to curb their fury, they can rush in from open sea, and fall with unbroken violence upon an exposed coast-line which has no bulwark of durable rock to oppose to their advance. That this is the case along some parts of the coast-line of the North Sea is shown by the form of the shores, the known effects of storms, and actual experiment of the power of the breakers. The force with which the waves of this ocean fall on objects exposed to their fury has been measured with great care at the Bell-Rock Lighthouse. This massive structure, rising 112 feet above sea-level, "is literally buried in foam and spray to the very top during ground swells when there is no wind." Experiments were made there from the middle of September 1844 to the end of March 1845, and the greatest recorded pressure was 3013 pounds on the square foot. Mr. T. Stevenson, however, informs us that on the 27th November 1827, the spray rose 117 feet above the foundations, being equivalent to a pressure of nearly three tons on the square foot,[1] and a ladder was wrenched from its fastenings at a height of 86 feet and washed round to the other side. Such enormous force cannot but produce marked effects on all rocks exposed to it. In May 1807, during the building of the lighthouse, six large blocks of stone which had been landed on the reef were removed by the force of the sea and thrown over a rising ledge to the distance of twelve or fifteen paces, and an anchor, weighing about 22 cwt., was thrown up upon the rock.[2] This power of transport from the surrounding sea-bed during severe gales has been frequently observed here. Stones measuring upwards of 30 cubic feet, or more than two tons in weight, have often been cast upon the reef from deeper water.[3] These large boulders

[1] *Trans. Roy. Soc. Edin.* xvi. 28.

[2] R. Stevenson, *Account of Erection of Bell-Rock Lighthouse*, p. 163.

[3] The sea at a distance of 100 yards all round the sunken reef of the Bell Rock has a depth of two or three fathoms at low water.

are so familiar to the light-keepers at this station as to be by them termed *travellers*.[1]

The Scottish coast-line from the mouth of the Firth of Tay to Stonehaven is formed of Old Red Sandstone, and displays with remarkable clearness the results of breaker-action on exposed shores. Its rocks, as is usual with those of that formation, present a picturesque succession of sea-cliffs of red sandstone worn into tunnels and solitary stacks, crags of hard volcanic rocks that seem ready to topple into the surf, creeks in which the gurgling tides are for ever rolling to and fro, caves sometimes out of reach of the waves, and then coated with mosses and ferns, sometimes at a low level, and filled well-nigh to the brim when the tide runs at its full, while the space between tide-marks is a chaos of craggy rocks and skerries, and scattered boulders. Such wild ruin as this might naturally suggest the operation of some cataclysm or convulsion of nature, some earthquake or outbreak of volcanic fire that has shattered the coast and strewn it with its own wreck. And some effort of imagination may be needed to realise that the devastation has all been caused by the very same agencies that are working it still, and notably by the breakers which, when the north-east gales sweep across the sea, batter against the cliffs with the noise of thunder, and cover them with spray even to the summit. The wall-like cliffs of red sandstone in the Forfarshire coast-line are perforated with curious blow-holes, like the "Geary Pot," near Arbroath, which bear witness to the long-continued assaults of the waves. Much more rapid is the waste in the creeks and bays where fragments of an older or upraised sea-beach are exposed to destruction. Thus, in the thirty years which preceded 1816, the road trustees were under the necessity of twice removing inland the roadway that skirts the shore westward from Arbroath, and in that year it had again become imperative to

[1] *Edin. Phil. Journ.* iii. 54.

make another removal.[1] The loss of land at one point, a short way south-west from the town, had been 30 yards since 1805, while at another spot still nearer the town it had reached in 1865 as much as 60 yards within the same period—that is at the rate of fully a yard every year. About the year 1780, a house existed at the latter locality, of which there are now no remains, its place being covered by the tides. At Arbroath itself, a house which stood next to the sea was some years ago washed down, and strong bulwarks are necessary to retard further encroachments. But these prove to be ineffectual barriers, for every severe gale damages them, and the sea is sensibly gaining ground.

The coast, as we proceed northwards, continues to furnish additional instances of the destructive effects of the sea within the historical period. "On the Kincardineshire coast," says Sir Charles Lyell,[2] "an illustration was afforded at the close of the last century of the effect of promontories in protecting a line of low shore. The village of Mathers, two miles south of Johnshaven, was built on an ancient shingle beach, protected by a projecting ledge of limestone rock. This was quarried for lime to such an extent that the sea broke through, and in 1795 carried away the whole village in one night, and penetrated 150 yards inland, where it has maintained its ground ever since, the new village having been built farther inland on the new shore." In order to check the further ravages of the waves, a stone bulwark was erected, which is still kept up for the protection of the houses that stand nearest the beach.[3]

Following the coast-line of Kincardineshire, we come upon one of the noblest ranges of sea-cliff along the eastern side of the island, where the characteristic forms assumed by the Old Red Sandstone are well displayed. The precipices of

[1] R. Stevenson, *Mem. Wer. Soc.* ii. p. 473.

[2] *Principles of Geology*, ninth edition, p. 302.

[3] *New Stat. Acc. Kincardine*, p. 275.

the Fowlsheugh shoot vertically upwards for more than 200 feet above the waves which have pierced their base with caverns and clefts and have isolated portions of them into stacks and skerries. Nowhere along this side of the country can the influence of geological structure in modifying and guiding the progress of marine erosion be more impressively beheld than on the cliffs between Bervie and Stonehaven. The gentle inclination of the strata of sandstone and conglomerate gives place to a gradually steepening dip, until among the picturesque headlands and gullies of Dunnottar the rocks are thrown on end, and continue in that position until they abut against the great Highland boundary fault.

At Stonehaven an example may be seen of one of the effects of sea-action on the drainage of the land. A storm beach of coarse shingle has been thrown up in front of the town, extending from the north side of the bay. The effect of this barrier has been to make the Cowie Water flow parallel to the coast for a third of a mile between the shingle ridge and the old shore-line behind. On the seaward face of the ridge a number of ledges cut in the gravel mark the height of successive storms.

The line of the Highland boundary fault runs out to sea immediately to the north of Stonehaven. Beyond it the Highland schists now occupy the shore. The wide diversities in the structure and durability of these rocks have given rise to a much more notched and irregular topography than that of the tracts of Old Red Sandstone. But the law of denudation is still maintained; the harder and more massive schists and eruptive rocks project in crags and promontories, while the more yielding members of the series are cut out into creeks and gullies. The Aberdeenshire coast, jutting well forward into the North Sea, is exposed to the fury of the easterly gales, and shows in its wasted lines of cliff how steadily the waves have been making way. As an instance of the force with which the breakers fall on these shores, reference

may be made to the gale of 10th January 1849, during which three successive waves carried away no less than 315 feet of a bulwark at Peterhead that had been built many years before at a height of 9½ feet above the high-water mark of spring-tides. One piece of this wall, weighing thirteen tons, was moved to a distance of 50 feet.[1]

Rounding the promontory of Kinnaird's Head, we see before us the long, straight coast-line of Banff, Elgin, and Nairn stretching westwards into the Moray Firth. Exposed to the full sweep of the north-easterly gales, portions of these shores have suffered considerable loss within historic times. At Gamrie, for instance, a selvage of sandy ground formerly intervened between the grassy slopes and the beach. A few years ago some of the older inhabitants still remembered when this sandy plain formed a small farm on which oats were grown. But this state of things has entirely changed. The farm has been swept away, the last relics of the dwelling-house have disappeared, and the waves, now reaching the edge of the grassy slope, have cut away its projecting parts, turning them into cliffs of red sandstone. Several yards of the cliff on the south-west side of Gamrie Bay have been removed by the sea within the recollection of the present generation.[2]

The shores of the Moray Firth present some interesting examples both of loss and gain of land. There is a tradition that the low tract between Lossiemouth and Burghead Bay was in the eleventh century a sea-strait through which the Danes piloted their war-ships. But owing to the remarkable way in which the tidal currents and waves drive shingle westward from the rocky Banffshire coast, and pile it up to the west of the Spey in ridges of gravel, there has been a great addition to the low ground of that region within the last few centuries. To this cause and the drifting of sand, Morayshire no doubt is indebted for having suffered less from the sea than her

[1] T. Stevenson's *Design and Construction of Harbours*, p. 55.

[2] Information given to me by Mr. Ingram, postmaster at Gamrie.

neighbouring counties. But where the coast-line projects in the range of sandstone cliffs, between Lossiemouth and Burghead, considerable loss takes place. An old fort, said to be of Danish origin, was built upon the sandstone headland of Burghead, between which and the sea, according to tradition, there once lay a considerable tract of land, but the ruin now actually overhangs the waves. The waste of these sandstone cliffs, which are about 60 feet high, appears to be mainly due to the influence of the atmospheric agents. The false-bedded strata are full of joints, which by the action of rain and frost serve to split off large blocks of stone that accumulate at the base of the cliff and protect it for a time from the sea. But these blocks are eventually broken up into rounded boulders and shingle by the waves, and in this way contribute to the burden of sand which is swept westwards. The waste of the cliff from meteoric influences seems to be too rapid to permit the waves to excavate a line of tunnels and sea-caves, though by sweeping away the fallen ruin they here and there allow the upper part of the precipices to overhang.

West of Burghead large accumulations of blown sand form a succession of dunes, beneath which lies the coarse shingle of the raised beach. A few miles farther on stands the town of Findhorn, which has been the scene of extensive devastations. The low and sandy shore at that place is liable to change its outline, owing to constant drifting of the sandhills. Between these ridges of sand and the sea margin there runs along the parish of Kinloss, west of Findhorn, a band of coarse gravelly shingle, which acts to some extent as a bulwark against the waves. But that it has proved an ineffectual barrier is shown by the fact that the present village of Findhorn is the third that has borne the name. The first stood about a mile west of the bar, the point at which the river originally entered the Firth, before the eastward progress of the moving sand drove it into the channel it now occupies. The second village was planted a little to the north of the present one, but it too has

been swept away. Nor does it appear that the existing town is free from the risk of being overtaken, partially at least, by a similar catastrophe. "The little space that intervenes between the tide-mark and the north end," says the reverend statist of the parish, "is a broken bank of sand that drifts dreadfully with every hurricane, covering the streets and gardens to the depth of sometimes 8 or 10 feet, and this constitutes but a feeble bulwark against the tremendous surf that beats with a north-easterly swell; so that if means be not taken to give it a solid surface, either by laying it over with turf or planting it with bent, there is reason to apprehend that it will by and by be blown away altogether, leaving Findhorn that now is to share at some future period the fate of its predecessors."[1]

Even into the upper reaches of the Moray Firth the ocean carries with it its resistless power of demolition. Thus, encroachments that had been made on the coast round Fort-George early in this century, were such as to raise fears for the safety of the fortress. Some of the projecting bastions, previously at a distance from the sea, were then in danger of being undermined by the water; and it was found necessary to break the force of the waves by erecting a sort of *chevaux de frise* in front of the walls. On the north shore of the Beauly Firth, a number of sepulchral cairns have been engulfed by the sea. One of these stands fully 400 yards within tide-mark, and it has been calculated that an area of not less than ten square miles, now flooded by the advancing tide, has been the site of the dwellings of the ancient cairn-builders.[2]

The long sheltered estuary of the Cromarty Firth, so thoroughly land-locked that it communicates with the open sea only through a narrow channel between the headlands of the two Sutors, might be supposed to be free from any risk of attack by the waves. Yet even there the same tale of waste is told. It was said by Hugh Miller that the tide in his time

[1] *New Stat. Acc. Scotland, Nairn*, p. 203.

[2] Wilson's *Prehistoric Annals of Scotland*, vol. i. p. 19.

flowed twice every twenty-four hours over the spot where a hundred years before there stood a pedlar's shop. The firth is fringed with raised beaches, of which the loosely aggregated sands and gravels are easily attacked and removed by the waves. I was told by a fisherman at Cromarty, in 1887, that he could then catch fish on the site of the cottage in which he was born. A wooden palisade filled in behind with earth and stones, at the upper margin of the beach, in front of the "fishertown" of Cromarty, had been put up in the previous year, but was at the time of my visit in great part destroyed, the sea having knocked out the timber and carried away much of the earthwork inside. The roadway between the houses and the line of high water will next be attacked, and unless some more effectual barrier can be provided, the houses themselves will follow in their turn. If the hardy and industrious but not very tidy fisher-folk are thus driven into the upper part of the town, the general character of Cromarty will be considerably altered.

To the traveller who skirts the north-eastern sea-board of Scotland, one of the most conspicuous landmarks is the cone of Morven, which rises on the far north-western horizon, and seems to terminate the range of uplands of eastern Ross-shire and Sutherland (Fig. 43). Beyond that conspicuous eminence lies the low plain of Caithness, which, from a distance, seems to be absolutely featureless. Reference to the geological map will show that this abrupt transition from the hilly ground south of Morven to the plain lying to the north nearly coincides with the line of boundary between the crystalline schists and the Old Red Sandstone. Though singularly monotonous in the interior of Caithness, the Old Red Sandstone compensates for this tameness by the boldness of its coast-scenery. It forms round the margin of the county an almost continuous line of mural precipice. Its two dominant structures, bedding and jointing, manifest their influence everywhere in the character of these cliffs. The strata, for the most part gently inclined,

consist of thin alternations of different varieties of flagstone, some of which withstand the weather better than others. The faces of the precipices are consequently etched out in alternate lines of cornice and frieze, on some of which vegetation finds a footing, while others are crowded with sea-fowl. By means of the vertical joints the rocks are split into clean perpendicular faces, which repeat themselves along the main cliff, on each inlet or "gio," and on every buttress and isolated stack (Figs. 13, 14, 17).

These ranges of precipice furnish every winter fresh proofs of the immense destructive power of the breakers of the North Sea. At some places, in particular to the south of the town of Wick, the waves have quarried out masses of flagstone and piled them up in huge heaps on the top of the cliff, 60 or 100 feet above high-water mark. Some of the blocks of stone which have been moved from their original position at the base, or on the ledges of the cliffs, are of great size. My friend, the late Mr. C. W. Peach, supplied me with the following notes regarding them. "The largest disturbed mass," he wrote in 1864, "contains more than 500 tons, and is known as Charlie's Stone. Others varying in bulk from 100 to 5 tons or less lie by hundreds, piled up in all positions in high and long ridges, which, before the march of improvement began in the district, extended far into the field above the cliff.[1] Near the old limekiln, South Head, similar large blocks of sandstone have been moved by the gales of the last three years. The

[1] This mass of ruin was noticed by Hugh Miller, who suggested that it might have been produced by the stranding of icebergs. Mr. Peach, however, remarked that there is every reason to believe it to be the work of the sea, and even now an occasional stone is added to the pile—a block at least half a ton in weight, about the year 1863, was torn up from its position 50 feet above the sea-level. I found, in visiting the locality in 1878, that the flagstone block, Charlie's Stone, above referred to, measures $13 \times 24 \times 24$ feet, and cannot weigh less than 576 tons. It lies 40 feet above high-water mark, and has been wedged out of its original position. Other blocks of smaller size, but still weighing many tons, have been knocked about by the breakers at heights of 60 and 70 feet.

FIG. 17.—Brig o' Trams, Wick. Cliffs of Old Red Flagstone, showing how the inward inclination of the precipices is determined by lines of joint, and how the faces of rock are etched out by weathering along the lines of bedding.

great storm of December 1862 in particular distinguished itself by the havoc which it wrought along these shores. It swept the sea over the north end of the Island of Stroma, which lies in the Pentland Firth,[1] and redistributed the ruin-heaps there. The waves ran bodily up and over the vertical cliffs on the west side, 200 feet in height, lodging portions of the wrecked boats, stones, seaweeds, etc., on the top. They rushed in torrents across the island, tearing up the ground and rocks in their course towards the old mill at Nethertown on the opposite side. This mill had often before been worked by water collected from spray thrown over these cliffs, but never had such a supply been furnished as by this gale. One curious phenomenon was noticed at the south end of Stroma; the sea there came in such a body between the island and the Caithness coast, that at intervals it rose up like a wall, as if the passage was too narrow for the mass of water which, forced onwards from the Atlantic between Holburn Head on the Caithness shore and the Old Man of Hoy on the Orkney side, passed bodily over the cliffs of Stroma. The effects of this terrific gale will long be remembered. Some time after its occurrence I was on Stroma and along the Pentland Firth side, and was deeply struck with the ruin spread around. The huge masses that had been moved exceeded all I had ever seen before. With this evidence, added to a long experience of storms, I am compelled to believe that the ruin of cliffs and the heaping-up of torn rock-masses have been effected by the sea when agitated by storms, and not by icebergs."

A few years ago on the northern coast of Caithness I

[1] The spring tides of the Pentland Firth run at a rate of 10.7 nautical miles in the hour, and are probably by much the most rapid marine currents round the British Islands. Yet that they do not of themselves produce any appreciable abrasion of the coast-line is shown by the coating of barnacles and sea-weed on the rocks even at low water. As currents, their power by mere friction is probably *nil;* but when they are aided by powerful winds they doubtless lend a much accelerated impetus to the ordinary wind-waves. Hence the incredible force of the breakers in these northern seas.

observed an interesting proof of the inroads of the sea upon

Fig. 18.—Stacks of Duncansby, Caithness. Old Red Sandstone.

the hard flagstones of that iron-bound shore. A "brough" or

"Pict's House," which, of course, had been originally entire, and had, no doubt, been built near the edge of the cliff for safety, was deeply trenched by the advance of a narrow gully in the precipice.

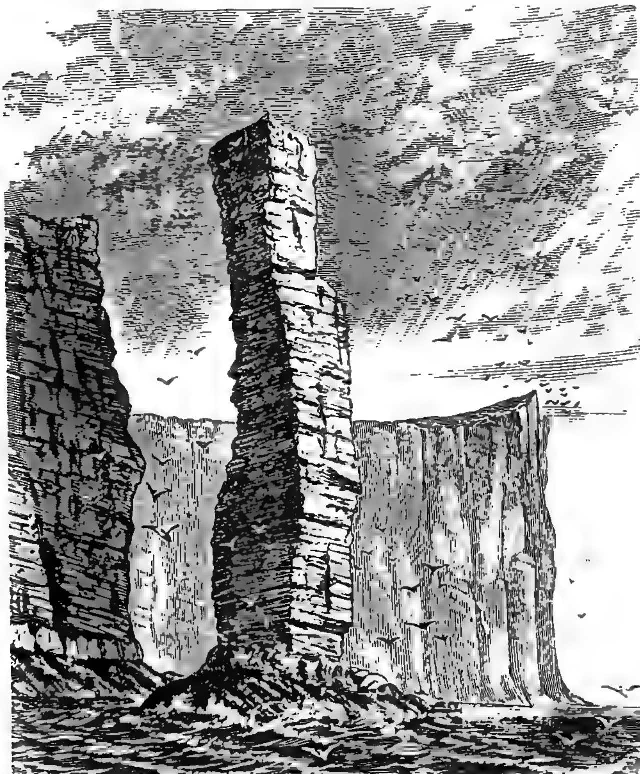

FIG. 19.—The Old Man of Hoy, Orkney. A stack of Upper Old Red Sandstone, 600 feet high, having at its base a zone of volcanic rocks which in turn rest upon the edges of tilted Lower Old Red Flagstones.

About forty-four miles north-west from Cape Wrath lies the remote Island of North Rona, once the place of retirement of a Celtic saint, and in more recent times the home of a small human

population, but now desolate and deserted. Placed far amid the melancholy main, this islet of gneiss furnishes some striking proofs of the power of the Atlantic gales. I found, on visiting the place in 1894, that on its north-western side the sea had quarried out a vast number of blocks of rock, and had piled them up as a large embankment along the coast at a height of 70 or 80 feet. The quantity of salt-water thrown across this ridge during gales is so great as to form streams, which, in descending eastwards into the sea, have cut deep channels through the turf into the gneiss below.

Beyond the dark flagstone cliffs and stacks of Caithness, we cross the wild tides of the Pentland Firth, and find ourselves among the rocky fjords and voes of the Orkney and Shetland Islands. There the power of the sea comes before us even more impressively. The intricate indented coast-line, worn into creeks and caves and overhanging cliffs; the crags, and skerries, and sea-stacks (Fig. 19), once a part of the solid land, but now isolated among the breakers; the huge piles of fragments that lie on the beach, or have been heaped far up above the tide-mark, tell only too plainly how vain is the resistance even of the hardest rocks to the onward march of the ocean. The rate of waste along some parts of these islands is so rapid as to be distinctly appreciable within a human lifetime. Thus, in the chain of the Orkneys, the Start Point of Sanday was in 1816 an island every flood tide; yet even within the memory of some old people then alive, it had formed one continuous tract of firm ground. Nay, it appears that during the ten years previous to 1816, the channel had been worn down at least two feet.

Probably no part of the British coast-line affords such striking evidence of the violence of the waves as may be seen along the margin of the Shetlands. These islands are exposed to the unbroken fury at once of the North Sea and of the Atlantic, the tides and currents of both seas running round them with great rapidity. Hence their sea-board wears in

many places an aspect of utter havoc and ruin. Against their eastern side, the North Sea expends its full violence, tearing up the rocks from the craggy headlands, and rolling onwards far up into the most sheltered fjords. On some of the projecting headlands the breakers, during easterly gales, burst with incredible violence and bury the cliffs in yeasty water and foam. Where the structure of the rocks favours the progress of demolition, narrow gullies or "voes" are cut out of the cliffs, at the end of which there is often a cave or tunnel, with an opening at the farther end of its roof, whence the

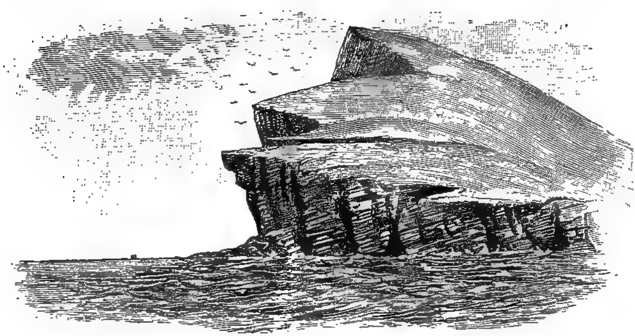

FIG. 20.—Noss Head, Shetland. A cliff of flagstone which overhangs, owing to the inward dip of its leading joints.

spray is ejected over the land. The flagstone cliffs repeat the mural scenery of the Orkney and Caithness coasts (Fig. 20).

A little farther north the crystalline schists of the main island are prolonged eastwards in a group of islets and skerries that project into the North Sea. Among these outlying islands, Whalsey, placed about the middle of the Shetland group, is completely sheltered from the gales of the Atlantic. Yet in the Bound Skerry of Whalsey, the breakers have torn up masses of rock sometimes 8½ tons in weight, and have heaped them together at a height of no less than 62 feet above high-water mark. Other blocks, ranging in bulk from 6 to 13½

tons, have been actually quarried out of their place *in situ* at levels of from 70 to 74 feet above the sea. One block of $7\frac{7}{10}$ tons, lying 20 feet above the water, has been lifted from its bed and borne to a distance of 73 feet from S.S.E. to N.N.W. over abrupt opposing faces of rock as much as 7 feet in height.[1] On the west side of the Shetland Islands the fury of the Atlantic has produced scenes of devastation which it is hardly possible adequately to describe. In stormy winters, huge blocks of stone are overturned or are removed from their native beds to a distance almost incredible. Dr. Hibbert found that in the winter of 1802 a tabular mass, 8 ft. 2 in. in length by 7 ft. in breadth and 5 ft. 1 in. in thickness, was dislodged from its bed and removed to a distance of from 80 to 90 feet. In 1820, he observed that the bed from which a block had been carried the preceding winter measured $17\frac{1}{2}$ ft. by 7 ft. and 2 ft. 8 in. in depth. The removed mass had been borne a distance of 30 feet, when it was shivered into thirteen or more fragments, some of which were carried still farther, from 30 to 120 feet. A block 9 ft. 2 in. by $6\frac{1}{2}$ ft. and 4 ft. thick, was hurled up the acclivity to a distance of 150 feet. "Such," he adds, "is the devastation that has taken place amidst this wreck of nature. Close to the Isle of Stenness is the Skerry of Eshaness, formidably rising from the sea, and showing on its westerly side a steep precipice, against which all the force of the Atlantic seems to have been expended: it affords refuge for myriads of kittiwakes, whose shrill cries, mingling with the dashing of the waters, wildly

[1] See an interesting paper by Mr. T. Stevenson, *Proc. Roy. Soc. Edin.* iv. 200; also his work *On the Design and Construction of Harbours* (1864), pp. 30-38. Mr. Peach, in a paper on the traces of Glacial Drift in the Shetland Islands (*British Association Report*, 1864), noticed further proof of the power of the breakers among these islands. On the top of the cliffs of the Island of Honsay, about 100 feet high, the waves break in stormy weather, tearing up the rock and piling its huge fragments into a semicircular wall a considerable way back from the edge of the cliff. "Between this wall and the cliff a deep river-like gully is scooped out, down which the water rushes again to the sea, a great distance from the spot whence it was thrown up."

accord with the terrific scene that is presented on every side." [1]

The result of this constant lashing of the surge has been to scarp the coasts of the Shetlands into the most rugged and fantastic cliffs, and to pierce them with long twilight caves. Dr. Hibbert describes "a large cavernous aperture, 90 feet wide, which shows the commencement of two contiguous immense perforations, named the Holes of Scranda, where, in one of them that runs 250 feet into the land, the sea flows to the utmost extremity. Each has an opening at a distance from the ocean, by which the light of the sun is partially admitted. Farther north other ravages of the ocean are displayed. But the most sublime scene is where a mural pile of porphyry, escaping the process of disintegration that is devastating the coast, appears to have been left as a sort of rampart against the inroads of the ocean. The Atlantic, when provoked by wintry gales, batters against it with all the force of real artillery—the waves having, in their repeated assaults, forced for themselves an entrance. This breach, named the Grind of the Navir, is widened every winter by the overwhelming surge, that, finding a passage through it, separates large stones from its side, and forces them to a distance of 180 feet. In two or three spots the fragments which have been detached are brought together in immense heaps, that appear as an accumulation of cubical masses, the product of some quarry." In other places, the progress of the ocean has left lonely stacks, or groups of columnar masses at a distance from the cliffs. Such are the rocks to the south of Hillswick Ness, and the strange tower-like pinnacles in the same neighbourhood called the Drenge, or Drongs, which, when seen from a distance, look like a small fleet of vessels with spread sails. Many "blowholes" have likewise been drilled in the roofs of sea-worn caves, and from these during storms sheets of foam and spray are shot high into the air.

[1] Hibbert's *Shetland Islands*, p. 527.

The most stupendous sea-cliff in Shetland towers some 1300 feet above the Atlantic on the west side of the Island of Foula. It consists of Old Red Sandstone, and bears impressive testimony to the variety and dignity of the rock-scenery which is characteristic of that formation along the coasts of Scotland.

The Hebrides, not less than the Shetlands, illustrate the power of the ocean in working the degradation of the land. The most careful observations yet made of the force of the breakers in this part of the British seas were those undertaken during the progress of the erection of the lighthouse on Skerryvore—a rock lying to the south-west of the Island of Tiree, and exposed to the full fury of the Atlantic, there being no land between this point and the shores of America. The average results of these experiments for five of the summer months during the years 1843 and 1844, give to the breakers a force of 611 lbs. per square foot; and for six of the winter months of the same years 2086 lbs. per square foot, or thrice as much as in the summer months. The greatest result obtained was during the heavy westerly gale of 29th March 1845, when a pressure of 6083 lbs. per square foot was registered. This was a force of little less than three tons on every square foot of surface. The next in magnitude was a force of 5323 lbs.[1]

North-west of Skerryvore lies the Island of Barra Head, the last of the long chain of the broken and deeply embayed Hebrides. It is recorded that on this island, during a storm in January 1836, a mass of gneiss containing 504 cubic feet, and estimated to be about 42 tons in weight, was gradually moved 5 feet from the place where it lay, having been rocked to and fro by the waves, until a piece broke off, which, jamming itself between the block and the rock below, prevented any further movement.[2]

[1] T. Stevenson, *Trans. Roy. Soc. Edin.* xvi. 25.

[2] *Ibid.* p. 28.

Fortunately the rock which has had to withstand this tremendous battery is a tough gnarled gneiss. But where the coast is low, and more especially where the hard gneiss

FIG. 21.—Cliffs of Archæan gneiss, Cape Wrath.

passes under a covering of blown sand, the Atlantic breakers have made sad inroads even within the last few generations. "The most destructive process of nature," says the author of the description of the Isle of Harris in the old *Statistical Account of Scotland*, "is the continual wasting of the land on

the western shore by the perpetual drifting of the sand, and the gradual encroachment of the sea. This is evinced by the clearest testimonies. Lands which were ploughed within the remembrance of people yet living, are now no more. Wherever a high sandbank has been entirely worn away, the soil under it is found to have been either a rich loam or black moss. In many such situations, vestiges of houses, enclosures, churches, and burying grounds appear."[1]

The results of long-continued marine erosion and of the manner in which these are modified by geological structure are likewise instructively displayed along the western sea-margin of the Scottish mainland. We may specially distinguish three types of sea-cliff there, each of which owes its peculiar characters to the internal structure of its component rock. These types are: (1) the crystalline schists, and more particularly the Archæan gneiss; (2) the red (Torridonian) sandstones; and (3) the basalt-escarpments. Of the first type the most striking examples are to be found in the great range of gneiss precipices which, rising to a height of 300 feet above the Atlantic, terminate northwards in Cape Wrath. The varying nature of the gnarled, crumpled gneiss, its irregular foliation and jointing, its bands of dark hornblende, and ramifying veins of pink pegmatite, conspire to give it very unequal powers of resistance in different parts of its mass. Consequently, it projects in irregular bastions and buttresses, and retires into deep recesses and tunnels, showing everywhere a ruggedness of aspect which is eminently characteristic (Figs. 21 and 29).

In striking contrast to these precipices are those of the second type—the Torridon sandstone—which, a few miles to the east of Cape Wrath, rise in vast vertical walls of rock to a height of 600 feet. These nearly horizontal strata are cleft by their perpendicular joints into quadrangular piers and projections, some of which even stand out alone as cathedral-like islets

[1] *Old Stat. Acc.* vol. x. p. 373.

Fig. [illegible].—Escarpment of the Basalt-plateau, Cliffs of Talisker, Skye.

in front of the main cliff. The sombre bands of dull red and brown are relieved by lines of vegetation along the edges of the nearly flat beds, which project like vast cornices, and serve as nesting-places for crowds of sea-fowl. At various parts of the coast-line, as far south as the mouth of Loch Carron, these red sandstones give rise to similar scenery, the cliffs of Handa Island being specially notable.

The third type, that of the basalt-plateaux, reaches its most impressive development along the west of the Island of Skye, where a magnificent range of precipices stretches for a distance of some 100 miles, and reaches at Dunvegan Head a height of 1000 feet above the sea. These ramparts of rock are built up of successive, almost horizontal, sheets of basalt which rise one over another like gigantic courses of masonry. The durability of the different bands varies greatly, and the system of joints by which they are traversed is much less defined than in the Torridonian and Old Red sandstones. Consequently the mural character is less prominently marked. Where the basalt is harder, as it is in the case of the intrusive sheets or sills, it rises with a perpendicular face, but the more decomposing lavas crumble into irregular belts, and not infrequently decay into steep slopes that support a coating of rich green grass. The contrast between the dark brown hue of the rock and the bright verdure that grows on it affords one of the most striking effects of colour in the Western Highlands (Figs. 22, 23, 49, 62, 64, 65).

It is worthy of remark that the coast-line of the mainland of Scotland, south from the Narrows of Skye to the Mull of Cantyre, though generally rocky, seldom rises into ranges of tall sea-cliff. The rocks have generally been intensely ice-worn, and their rounded domes and bosses plunge into the sea with no intervening strip of beach, save in the bays and inlets. The younger schists, although they present craggy slopes and lofty precipices in the interior of the Highlands, often assume comparatively tame outlines where they descend into the sea.

Nowhere do they furnish such lofty and picturesque precipices as those that form so much of the magnificent coast-scenery of Donegal and Mayo. Every traveller must remark the general absence of high cliffs along the coasts of Argyllshire and Inverness-shire, and the comparative insignificance of such cliffs as do occur. Some of the most conspicuous exceptions to this rule are supplied, not by the schists, but by rocks of much younger date. The precipices of Ardnamurchan,

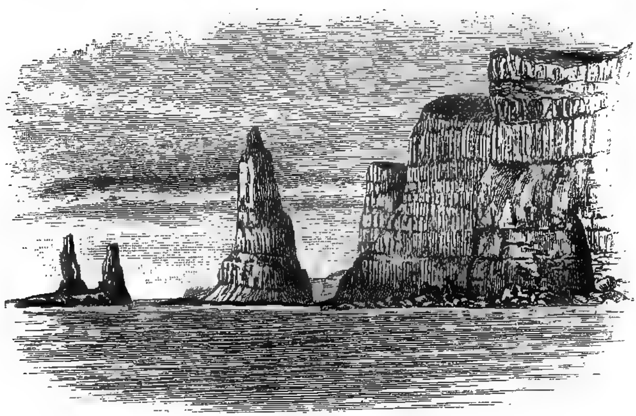

FIG. 23.—Macleod's Maidens and the basalt cliffs of the west of Skye.

for example, consist of Tertiary igneous masses; those near Oban belong to the Old Red Sandstone.

By the chain of the Hebrides, which lies like a great breakwater, the western coast of Scotland is no doubt in some measure protected from the full force of the Atlantic breakers. The greater hardness of the rocks, as compared with those of the east coast, may also have contributed to retard the progress of the waves. Nor must we forget that the absence of harbours, maritime villages, and towns on the western sea-board has probably deprived us of a record of the waste of these shores within the historical period. Knowing the actual force of the

waves, and seeing how much they can effect in a stormy winter, we cannot doubt that during the last few hundred years there must have been considerable loss of land at some parts even of that iron-bound coast.

That such loss can be proved to have taken place even in the more sheltered parts of the western sea-board may be regarded as good evidence of the general loss of land. In the Kyles of Bute, a tract of low ground to the north of Kames Bay has been so encroached upon by the tides that a road which skirted the beach had been thrice moved farther inland during the thirty or forty years that preceded 1864.[1] Along the shores of the estuary of the Clyde, the sea has in some places removed a considerable part of the coast-line even within recent times. To the south of the town of Ayr, a cliff of volcanic tuff rises vertically from the beach, bearing on its verge the picturesque ruin of Greenan Castle. The walls overhang the precipice, and the sea is hollowing out the rock below. Yet within the recollection of a venerable lady who died some years ago, there was room for a horse and cart to pass between the castle and the edge of the cliff. During the last hundred years, therefore, a slice of solid rock, perhaps six or eight feet broad, has been cut away from this part of the coast. A short distance farther south, a spring in the middle of a field, a few feet above high-water mark, was enclosed as a well some eighty or ninety years ago. Since then that part of the field which lay between the well and the sea has been eaten away, and the spring now rises at the edge of the shingle of the beach.[2]

On the west side of the country, the same groups of Silurian strata which on the east side give rise to the great sea-cliffs of Berwickshire furnish ranges of similar though less lofty preci-

[1] My much-esteemed friend the late Rev. Alexander Macbride, of Ardmory, Bute, pointed this fact out to me in 1864.

[2] These facts were communicated to me by the late Dr. Sloan, of Ayr, in 1863.

pices along the coasts of Wigtonshire and Kirkcudbright. Here again we may infer, from the recorded inroads of the sea in sheltered situations, that the more exposed and rocky parts of the coast must be undergoing a measurable amount of waste. The shores of Loch Ryan, which seem so well protected alike from the Atlantic and the Irish Sea, have suffered considerably within the last two or three generations, the soft glacial deposits and raised beaches which there fringe the coast having yielded to the encroaching sea. Mr. Stevenson found in 1816 that at the town of Stranraer the houses along shore had formerly gardens between them and high water, but that of late years the inhabitants had been under the necessity of erecting bulwarks to secure the walls and approaches to their houses. Farther down the loch, at the village of Kirkcolm, a neck of land called the Scar Ridge had once extended into the sea about half a mile. Cattle were wont to graze upon it, but it was then nearly washed away, and in high tides it was laid almost wholly under water.[1]

Though the waves in the comparatively enclosed waters that wash the south-western shores of Scotland have not the magnitude of those of the Atlantic or North Sea, yet when they are driven landward from the south-west across the full breadth of the Irish Sea they fall with accumulated force upon the land. Thus, during gales the rocky precipitous shores of Wigton and Kirkcudbright are white with foam, headland after headland standing out into the breakers that roll eastward far up into the recesses of the Solway Firth. In a series of experiments made during the fine summer of 1842, at the Island of Little Ross, on the coast of Kirkcudbright, it was found that the average force of the waves was about 328 lbs. on the square foot, or rather more than half the average summer force of those at Skerryvore, the greatest recorded pressure being one of 664 lbs.[2] The effects of these breakers are seen in the narrow gullies,

[1] R. Stevenson, *Mem. Wer. Soc.* ii. 476.

[2] T. Stevenson, *Trans. Roy. Soc. Edin.* xvi. 30.

clefts, stacks, and arches into which the greywacke has been sculptured (Fig. 24).

From this short and incomplete survey of what has been done by the waves round the Scottish coast during the last two or three hundred years, it is evident that only here and there from local causes has there been a slight gain of land. These exceptional places may be seen at the heads of estuaries where alluvial deposits are made from the sediment borne sea-

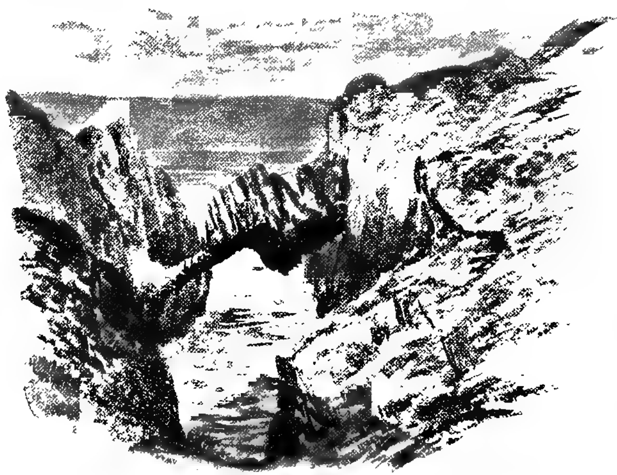

Fig. 24.—Gully and natural arch in Silurian greywacke and shale, Shore, Mull of Logan, Wigtonshire.

wards by rivers, and in sheltered bays into which sand and silt are swept by prevalent winds and tidal currents. Occasionally also on more exposed situations, where large accumulations of shingle are thrown up between tide-marks, a severe gale coinciding with the time of high water may drive the shingle much above the usual limits reached by the waves. Such *storm-beaches*, as they are called, may long remain as barriers against the advance of the sea (Fig. 67*a*). It is not always possible to

discriminate between them and the younger raised beaches which mark a rise of the land.

From the foregoing narrative it will appear that along the whole coast-line of Scotland, the general result of the action of the sea has been a loss of land. Where the coast is rocky and precipitous, this loss may be inappreciable, yet the ruined masses, undermined by the waves, tell their story not less convincingly than where there are historical records of the devastation.

Looking at the general results of the erosive work of the sea, we are led on reflection to perceive that they tend to the ultimate formation of a tolerably level surface, or what geologists call a *plain of marine denudation.* As it is only the uppermost layer of the sea—the part thrown into commotion by

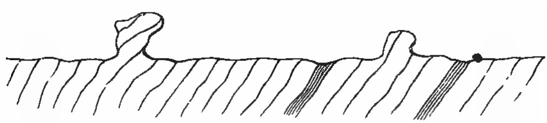

FIG. 25.—Inclined Silurian strata near Girvan, cut into a plane surface by the sea.

disturbance of the atmosphere—which possesses any efficient power of abrasion, the effect must be, not to cut out valleys, but to eat into the land horizontally, and reduce it to a general level under the waves. This tendency is sometimes well illustrated on a small scale on a rocky beach. To the south of Girvan, for example, the Ayrshire coast exhibits, between tide-marks, a smooth level platform of Silurian greywacke, indenting the line of rugged crags which run along high-water mark (Fig. 25). This platform has been cut out of nearly vertical strata, some of which, being harder than their neighbours, rise above it into fantastic knobs and bosses. It abounds in cavities lined with sea-weeds and filled with sea-water—each a natural aquarium; and in some cases, at least, it is evident that these hollows are simply *pot-holes*, like those in the channel of a river, save that the boulders

which lie at their bottom have been kept whirling round in the eddies of the tide, instead of a rapid brook or river. The level platform, with its hollows and outstanding crags, is a plain of marine denudation, and illustrates, on a small scale and in detail, a process of which the more gigantic results will be considered in succeeding chapters.

But, as I have already stated, we should ascribe to the sea too great a share in the process of denudation were we to regard such a plain as mainly the work of the waves. These give it, indeed, its characteristic flatness, and put the last touches to its sculpture. But all the previous long record of waste, during which the land was worn down nearly to the sea-level, was one in which the sub-aërial agents almost alone were concerned. These agents, rotting, sawing, filing, scraping, grooving, polishing, continue their operations as long as any land remains above the sea. As the result of their combined action, a land-surface may be reduced nearly to a plain even before it is worn down below sea-level. It is true that the sea is also at the same time cutting away the margin of the land. But the area exposed to its attacks is a mere insignificant fraction of the whole extent of land which is subject to sub-aërial disintegration, and long before the waves could remove a strip, even a mile or two broad, from the edge of the land, the other denuding forces, working at the same rate as at present, would have reduced the dry land to the level of the sea. A plain of marine denudation, therefore, represents a base-level of erosion—the downward limit to which all the denuding agents, sub-aërial and marine, have reduced a mass of land, and beneath which further erosion ceases, because the ground, having reached the lowest level to which the denuding agents can act, is thereafter protected by being covered by the sea. It is approximately a plain, because its erosion cannot be continued below a certain average depth under the surface of the sea. But it must, doubtless, present many minor inequalities of surface, some parts

remaining higher because of their superior capacity for resistance, or because of their lying less exposed to the grinding action of waves and currents which elsewhere have lowered the level of the bottom.

The sea between the British Isles and the coasts of the continent, from the south of Norway to the north-western headlands of France, is so shallow, that an elevation of only 600 feet would convert it all into dry land, except a long deep valley near the Norwegian coast. This wide submarine plain, if we consider the geological structure of the terrestrial areas that surround it, is undoubtedly a plain of erosion. Originally it was a portion of the general mass of the European continent. By a succession of geological changes it was reduced to a base-level of erosion and submerged under the sea. After reaching that condition, it was re-elevated into land, and served as the terrestrial platform across which the present plants and animals of Britain found their way hither. By means of the charts of the North Sea, it is possible to trace some of the submerged terrestrial features of that ancient land-surface. The Mesozoic escarpments of Eastern England can be seen to stretch far eastwards under the sea, breached here and there by the seaward prolongation of the channels of the present streams. Our rivers at that time were no doubt tributaries of some of the larger rivers of the continent, the Thames, for instance, winding across the plains until it emptied into the Rhine, and the whole drainage passing northward until it was discharged into the sea by some vast river, greater than any modern European stream, between the Shetland Isles and the coast of Norway. Since that time this ancient terrestrial plain has sunk once more beneath the sea, the waves and currents are now wearing down the tops of its ridges, and strewing sand, gravel, and mud across its hollows; and by the constant gnawing away of the land on either side, its area is slowly being widened.

CHAPTER IV

GLACIERS AND ICEBERGS

Up to this point, the tools of earth-sculpture which we have been considering are all such as can be seen in actual operation in Scotland at the present time. In some cases, indeed, the vigour with which they are plied here is much less than in other parts of the world. Great as is the amount of wasted rock carried into the sea by an exceptionally heavy flood or "spate" in this country, it is small, indeed, when contrasted with the rivers of mud which, during the rainy season in tropical climates, sweep down from the land, and help to heap up the long alluvial bars that, for such vast spaces, keep the sea, as it were, barred off from the land. Again, we should have but a limited conception of the potency of frost if we took, as our type of its action, merely what we can here observe from winter to winter. Still, the action is the same in kind everywhere, and no one who has thoroughly observed it as it goes on in his own country, can have much difficulty in realising what it must be in other lands.

But all the tools which Nature has used in the carving of the earth's surface are not to be seen now at work in Britain. Notably is this true of one which, at a date not by any means remote in a geological sense, was in active operation all over the British Isles. Except along the southern belt of England, between the Bristol Channel and the mouth of

the Thames, there is abundant evidence that the surface of these islands, like the rest of the northern parts of Europe and America, has been modified by some kind of natural agent, very different in its effects from any of those which have been noticed in the foregoing chapters. Had the features of these northern regions been carved only by air, rain, springs, rivers, and frosts, their general outlines would have been more rugged than they are. The valleys would oftener have had scarped sides, the hills would have been sharper in form, and more deeply cleft with gullies and ravines. There would have been such an angularity of topography as one can witness on a crag or crest long exposed to sub-aërial disintegration. And above all, there would have been on the mountain slopes, on the plains, and in the valleys, a prodigious accumulation of debris, the result of slow decomposition and degradation during thousands of years. But these various features are conspicuously absent. The hills and valleys, instead of showing the full angularity of sub-aërial decay, wear a general smoothness of contour; their accumulated debris has been scraped off them, and their bare rocks project in rounded domes and hummocks, or are concealed under a cover of detritus which has to a greater or less extent been transported from a distance. Evidently some abrading agency has in large measure worn off the old roughnesses, and given a flowing outline to the ground. The fuller proofs of this statement will be given in a future chapter.

In the meantime, by way of illustration and explanation, let me briefly refer to the aspect of the deep inlets by which the Atlantic rolls its tides far into the heart of the great mountainous tracts of the Western Highlands. Fronting the sea, as on the coast about Arisaig, a scattered group or chain of islets rises out of the water—little bare rocky bosses, like the backs of dolphins. Inside this natural breakwater, the fjord or sea-loch, deeper, perhaps, than the sea immediately outside, winds inland between lofty mountains. On either

hand, the rocks of the valley slip down into the sea, with the same smoothed outlines. It is the loftier crests and peaks, shooting far up into the colder layers of the atmosphere among the frosts and clouds, which show angular spiry forms, that contrast strongly with the smoothed flowing contours of the lower slopes. These summits are formed of precisely the same rocks as the roots of the hills. Why then should they present contours so different?

With these features fresh in his memory, let the observer transport himself in imagination to the west coast of Norway. His first impression there will probably be almost one of doubt whether he really has quitted the Scottish shores, so precisely similar in their essential features, and even in their details, are those of Western Scandinavia. As he ascends one of the fjords, he sees around him the same smoothed and polished islets, the same flowing outlines on all the lower hills, and the same craggy crests against the sky. But at the far head of the winding inlet, he will find that, in the northern part of Norway, the sea-filled valley passes inland into a deep glen, down the centre of which a glacier creeps, while snow-fields descend to the very edges of the precipices all around (Fig. 26). He will discover that the smoothed rock-surfaces pass under the glacier, and he may then, as it were, catch the ice in the very act of producing them. A glacier 1000 feet thick—and many modern glaciers attain greater dimensions—exerts on each square foot of its rocky floor a pressure equal to about twenty-five tons. Pressing onward the sand and stones that lie between it and the rocks over which it moves, it is a powerful grinding machine, that smooths, polishes, scratches, and grooves even the hardest rock (Figs. 73, 74). The rounded, polished domes of rock in these Norwegian valleys have all been ground down by the passage of the glaciers across them. The abundant scratches and groovings traced upon them show the direction of the movement of the ice as it held in its grip the sand and stones which it pressed steadily upon the rocks

beneath. No one can view these scenes without being power-

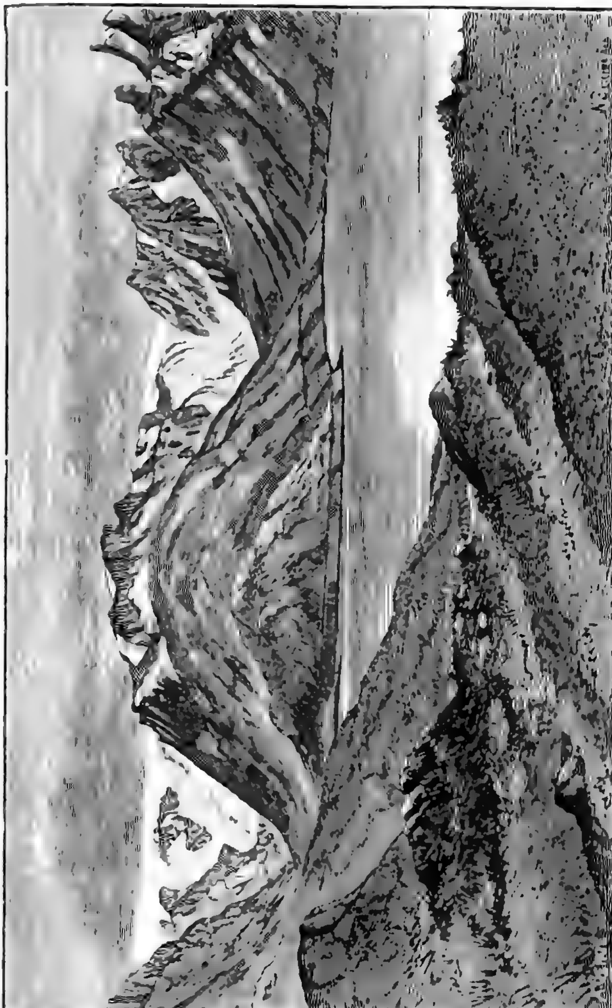

Fig. 26.—View of the glaciers at the head of the Nus Fjord, Northern Norway.

fully impressed with the evidence that the modern Scandinavian

glaciers are the mere shrunk remnants of those which once filled up the fjords for hundreds of feet above the present sea-level, buried all the lower hills, and marched boldly out into the Atlantic.

Now, there can be no doubt that Scotland once nourished glaciers in all her larger glens, as Norway still does, for the ice-marks are not less distinct here than they are among the northern fjords. But there was still an earlier time, when not only were the valleys filled with local glaciers, but when the whole country was swathed in snow and ice. The evidence for this condition of things will be stated in later chapters. To realise what was the condition of this country when the ice-fields that lay upon it were thickest, we must turn still farther north. The present aspect of the northern and eastern parts of Greenland probably presents a close parallel to the condition of Scotland at the height of what is known as the Ice Age or Glacial Period. The interior of that tract of country is deeply buried under one vast sheet of snow and ice, which, constantly augmented by fresh snowfalls, moves steadily downward from the axis of the continent to the eastern and western shores. This vast *mer de glace* sweeps inland, league after league, in one interminable glacier, broken only here and there by some black hill-top or mountain peak, that rises as an island (or *nunatak*) out of the snow. It covers the face of the country to a depth of hundreds, or even, in some places, thousands of feet, filling up the valleys, mounting over the hills, and pressing with constant resistless force upon all the rocks over which it marches, till it reaches the sea, into which from each main valley it protrudes a long way from the shore, rising above the waves as a solid glassy wall, sometimes more than 300 feet high, which breaks up into huge fragments, that rise and float away as icebergs.

If a single glacier, descending below the snow-line, as in Norway and Switzerland, can grind down, polish, and score the rocks of its channel, it is easy to see how vast and constant

must be the erosion carried on by so huge and heavy a mass of ice as that which creeps over the whole of North Greenland from mountain top to sea-shore. Could we strip off this icy mantle, we should find the surface of that country worn into rounded and flowing outlines, its valleys and hills smoothed, often with hollows and deep rock-basins ground out of them, and its rocks covered with ruts and grooves, that would mark the direction of the march of the ice. It would, in short, so far as we can tell, bear the closest resemblance to the smoothed and polished aspect of Western Scandinavia and the Highlands of Scotland. The ice has so long retired from our mountains and glens that the peculiar contours which it impressed upon them have had time in more exposed situations to be in some measure broken up by the disintegrating influence of the weather. But the effects of the glaciation are in many places still so fresh that it is difficult to believe that ages have passed away since the ice vanished. These ice-worn rock-surfaces, so universal and so distinct, afford materials for forming a vivid mental picture of the general aspect of this country when the rigorous climate of the Ice Age was at its height.

We see, then, that one of the most notable of Nature's sculpture-tools, land-ice, though no longer at work in Scotland, has left its characteristic marks all over the country. The detailed account of how Scottish scenery has been influenced by ice-action will be given in later chapters. But besides grinding down, smoothing, polishing, and grooving the rocks, ice-sheets and glaciers leave other memorials of their presence. Where a country is buried, like Northern Greenland, under a wide mantle of ice, the covering of rotted rock which may have gathered over its surface, during long previous ages of sub-aërial decay, is scraped off and pushed onwards to lower levels under the slowly creeping ice-sheet. Fresh debris detached from projecting points of land finds its way down crevasses to the floor below, and the accumulated detritus is ground down under the ice, while at the same time it becomes the material by

which the solid rocks beneath are scored, polished, and abraded. Such was probably the origin of the *boulder-clay* or *till* which has been spread over the lower grounds of Britain, and which can be traced up to the glens and corries of the mountains from which the ice-sheet radiated.

Again, evidence of a less intense form of glaciation is shown by traces of valley-glaciers. In a valley of which the bottom is filled by a glacier, the frosts, thaws, and rains of every year loosen large quantities of debris, much of which ultimately comes to rest upon the ice. As the glacier threads its way down the valley, its surface becomes discoloured with the earth, stones, and mud washed from the slopes; piles of rubbish collect along its sides in long lines called *moraines*. These are slowly borne onward upon the ice, till at last, when the glacier melts, they are thrown down. The confused heaps of earth and stones thus formed are apt to be washed away by the escaping river, as fast as they are deposited. Where, however, they remain, they form along or across the valley a more or less continuous rampart, which is continually growing by the addition of fresh materials brought down by the ice. Should a period of milder temperature come and cause the glacier to retire up the valley, this rampart-like pile of rubbish will be left behind to mark where the ice once reached. Another prolonged halt at a higher part of the valley will give rise to another set of moraine mounds. And thus, by the intermittent recession of the glacier, successive lines of such piles of debris may be thrown down, each line marking a pause in the retreat of the ice, and a sojourn of the glacier-end at that place. Now, as will be afterwards pointed out, this characteristic relic of glacier work is to be found in many Scottish valleys. Moraine mounds, singularly fresh, still dam up the drainage from the surrounding slopes as they did when the ice drew back from them (Figs. 54, 82, 92, 93), and huge boulders, once carried on the ice from the higher recesses of the hills, still lie scattered on the heaps of rubbish, or

perched on hill and crag where the ice dropped them (Figs. 73, 74, 75, 76, 81, 91).

So abundant and so marvellously fresh are the traces of the vanished glaciers in many Highland glens that no great exercise of the imagination is needed to bring back the snow-fields in the mountain-basins, to fill the corries with snow and ice, and to follow the glacier as it bears downward its heaps of moraines. If by chance we can visit such a scene in winter, when the heights are white, and thick drifts of snow have buried the upper part of the glen, the past stands out once more before our eyes. We seem to see

"The glaciers creep
Like snakes that watch their prey, from their far fountains,
Slow rolling on; there many a precipice
Frost and the sun in scorn of mortal power
Have piled—dome, pyramid, and pinnacle,
A city of death, distinct with many a tower
And wall impregnable of beaming ice.
Yet not a city, but a flood of ruin
Is there, that from the boundary of the skies
Rolls its perpetual stream; vast pines are strewing
Its destined path, or in the mangled soil
Branchless and shattered stand; the rocks, drawn down
From yon remotest waste, have overthrown
The limits of the dead and living world,
Never to be reclaimed.
Below, vast caves
Shine in the rushing torrents' restless gleam,
Which, from those secret chasms in tumult welling,
Meet in the Vale; and one majestic River,
The breath and blood of distant lands, for ever
Rolls its loud waters to the ocean waves." [1]

While land-ice is a most powerful geological agent in new-modelling the surface of the earth, its operations are not entirely confined to the dry land. Where it descends into the sea, it may creep along the sea-bottom for some distance from land, until flotation comes into play, when large masses break

[1] Shelley, *Poems of 1816*, "Mont Blanc."

off from the ice-cliff, and rising up and floating, sail away seaward as icebergs. These ice-islands carry with them any soil or rock-rubbish which may have fallen upon them from inland cliffs, while they formed part of the ice-sheet of the country. The debris so borne off is, of course, thrown down upon the sea-bottom, as each berg melts away after a voyage of perhaps hundreds of miles. Year by year, whole fleets of these bergs are sent southwards in the arctic regions, so that the bed of the northern seas must be strewn with earth and boulders. As only between an eighth and a ninth part of a mass of ice appears above the sea-water on which it floats, the bulk of many bergs must be enormous. One rising 200 feet above the waves—not an uncommon height—must have its bottom more than 1700 feet below them, and the thickness of the arctic ice-cap at its outer edge must be about 2000 feet. The antarctic ice-sheets and icebergs are of still more colossal dimensions.

Deeply seated in the water, bergs are acted on much more by marine currents than by winds. Hence, they are sometimes seen careering through a frozen sea in the teeth of a tempest, breaking up the thick-ribbed ice before them with a noise like the loudest thunder, yet with as much apparent ease as a ploughshare cuts the loam. Every winter, crowds of bergs are firmly fixed in the frozen sea of the arctic regions, and when summer comes, the united mass drifts southwards towards Newfoundland. Vast floes of ice, larger sometimes than the whole of Scotland, with embedded ice-hills rising 200 feet or more above the sea-level and sinking 1700 feet or more below it, are thus borne by the ocean-currents into warmer latitudes, where they break up and disappear. When such current-driven masses grate or strand on the sea-bottom, they no doubt tear up the ooze, and bruise and scratch the rocks. In the course of long ages, a submerged hill or ridge may have its crest and sides much bruised, shorn, and striated, and the sea-bed generally may be similarly

grooved and polished, the direction of the striation being more or less north and south according to the prevalent trend of the drifting ice. In some of the younger deposits of Scotland, there are indications that the lower parts of the country were submerged in an icy sea across which floes and bergs drifted to and fro. There can be no doubt, however, that the general smoothing and striation of the surface of the country has been the work of land-ice and not of icebergs.

CHAPTER V

THE HISTORY OF A LAND-SURFACE

HAVING now, as it were, watched the employment of each of the implements wielded by Nature in the process of sculpturing the surface of the land, let us briefly consider the combined effect of the co-operation of the whole of these processes upon the landscapes of a country possessing such a climate and geological structure as Scotland. In the first place, as the result of the influence of the air, changes of temperature, rain and frost, there is a general disintegration of the whole surface of the land. Even the most obdurate rocks cannot permanently resist this decay, while the softer kinds yield to it with comparative rapidity. The crumbled materials are ready to be blown away by wind or to be washed off by rain, leaving new surfaces exposed to a continuation of the same ceaseless attack. While the general surface of the land suffers, scope is afforded for the manifestation of differences in the degree of resistance to the progress of destruction. The harder rocks are gradually left projecting above those which, being softer, are more readily abraded.

The lines by which the drainage of the land is carried out to sea are liable to specially vigorous erosion. The detritus produced by sub-aërial waste is washed into the rivers, and the coarser parts are employed by the running water in scouring its channels, which are thus deepened and widened, and sink inch by inch farther into the framework of the land.

Under favourable conditions of climate and geological structure, the streams dig out long and deep ravines in solid rock; but more usually their work is made less obvious by the activity of the other sub-aërial agents, which attack the sides of the water-channels and lower them as fast as the streams can deepen their beds. By this combination of operations, valleys with sloping sides are hollowed out.

In those regions where the atmospheric moisture generally falls to the ground as snow, land-ice is formed, which, when it assumes the character of an ice-cap or of distinct valley glaciers, moves downwards from the higher grounds, grinding, smoothing, polishing, and scratching the rocks over which it marches, hollowing them out into basin-shaped cavities in one place, and leaving them as projecting domes and bosses in another, but everywhere removing their accumulations of decayed material and transforming that angularity of feature which they naturally assume under the ordinary influence of the weather into those characteristic, smooth, flowing contours, which are so marked a relic and evidence of ice-action.

Lastly, the sea cuts away slice after slice from the margin of the land. Here and there indeed, whether from the sediment carried down by rivers or from that which the tides and waves cast ashore, a gain of land from the sea may be recorded. But such additions are merely local, and are generally insignificant. They do not seriously affect the conclusion which the evidence forces upon us, that, on the whole, the sea encroaches on the land, and will continue to do so as long as any dry land is left above its level.

Such, then, is the order of nature as we see it now. The surface of this country, and indeed of all the great terrestrial areas of the planet, is undergoing a continuous process of denudation, during which many inequalities of contour are worked out, but the ultimate result of which, if unchecked by any counterbalancing natural agency, must be to reduce the dry land to the level, or rather a little below the level of the

sea. The limit beneath which there is little effective erosion by waves and tidal currents probably does not exceed a very few hundred feet. Worn down to that limit, the degraded land will become a submarine plain, across the surface of which younger deposits may afterwards be strewn.

In speculating, however, from ascertained facts as to what may be or what has been the history of a land-surface, we are of course bound to take into consideration the effect of subterranean movements in modifying changes at the surface. It is evident that even if no disturbance were made in the drainage-lines of a country, upheaval, by increasing the declivity of the streams, would quicken their scour, and not improbably add to their volume by augmenting the rainfall. Subsidence, on the other hand, would have the contrary effect, and would carry down part of the land out of reach of atmospheric disintegration. It is certain that in the geological past there have been many uplifts, by which the solid terrestrial crust has been plicated and fractured on a colossal scale. Such a chain of mountains as the Alps, for instance, exhibits proofs of stupendous inversions and folds, whole mountainous masses of rock having there been uprooted and pushed bodily over younger formations for distances of miles. But while the proofs of prodigious displacements are so clear, it is by no means so evident how they affected the surface of the ground at the time, or what relation the present topography bears to that which was left at the close of the great uplift. This is a question which ought not to be merely guessed at. To assume, for instance, that the existing contours of a range of mountains are essentially those which it received at the time of its upheaval is wholly inadmissible. We may be ultimately brought to that conclusion, indeed, but it ought to be reached by a careful examination of the actual structure and forms of the mountains.

Now, one of the most striking facts which every mountain-chain, even the youngest, thrusts prominently into notice is the

proof that, great as have been the subterranean movements to which the chain owed its birth, they are hardly more remarkable than the extent to which the uplifted ground has subsequently been denuded. From summit to base, on crag, crest, and ravine, the story of universal denudation is written in signs that cannot be misread. The minimum amount which has been removed from some parts can be measured, and is found to be so great, that if it could all be put back again where it once lay, it would entirely fill up deep and wide valleys and completely alter the form of the mountains. From this evidence, it is demonstrable that the present topography must be widely different from that which the mountain-chain originally wore. If we only reflect upon the work that is now being done before our eyes by running water everywhere, upon the amount of sediment which can be shown to be carried every year from the land into the sea, and upon the rate of waste of the general surface of the land which the removal of this material proves, we are compelled to admit that no terrestrial forms of surface can possibly escape transformation by superficial agencies, and that the older a land-surface is the more unlike must it be to its first aspect. So continuous and extensive is this transformation that to speculate upon what may have been the earliest configuration of any land-surface may be an idle and useless occupation. But as regards the denudation of the area, there is no room for doubt or speculation. Even the youngest additions to the breadth or height of a continent bear witness to the ceaseless waste which it has suffered. There usually remain outlying fragments which suffice to prove at least the minimum amount of material that has been worn off the land. But the actual amount is probably always far beyond what is thus shown.

While, then, the facts of denudation are thus easily established, the influence of subterranean movements seems always to elude our search. To that influence we know that the elevation of each terrestrial area on the surface of the globe

and the uplifting of each mountain-chain were due. We can realise also that the same cause may from time to time have intervened to accelerate or retard, or even to efface, the work of land-sculpture. But the more we consider the present operations of the sub-aërial denuding agents, the more shall we be convinced that a system of hills and valleys, with all the local varieties of scenic feature that now diversify the surface of the earth, may be entirely produced by denudation, without further help from underground forces than the initial uplift into land. No matter what may be the original configuration of the mass of land, the flow of water across its surface will inevitably carve out a system of valleys, and leave ridges and hills between them.

These general principles find ample illustration in the history of the scenery of Scotland. In this country, the ranges of hills and valleys furnish evidence of some of the greatest terrestrial displacements in Western Europe. Yet these subterranean movements are not conspicuous at the surface by any imposing landmarks. On the contrary, they require to be carefully sought for, and in many cases only a trained geologist can discover the traces of them. By bringing hard and soft rocks next each other, and by rearranging the constituent masses of the land, these subterranean movements have undoubtedly influenced the progress of denudation. But they have not done so in any masterful fashion. On the contrary, they have influenced local details of topography rather than the main physical features of the country. Even where they have been most powerful, they have left so little trace of their action in any outward topographical feature, that they were not only not recognised, but were completely misread, by some of the most experienced geologists of the day, who regarded as evidence of undisturbed and continuous deposition of sediment what we now know to be evidence of the most gigantic upthrusts of which any memorial remains in the British Islands.

In dealing with the evidence of such great terrestrial dis-

placements, as I shall do more in detail in later chapters, we must always bear in mind the lapse of time that has intervened between their geological period and our own. So ancient are some of them, such as those of the North-west Highlands of Scotland, that the land may have been reduced to a submarine plain several times over in the long interval. Any effect they may originally have had upon the surface has been utterly effaced long ago, and before the present valley-system began to be carved out. How this statement can be substantiated will, I hope, appear clearly enough in later parts of this volume. I make it now at the outset, in order that the reader may recognise that a belief in the paramount efficacy of superficial denudation in the origin of the features of the land is compatible with the fullest admission of the existence and potency of subterranean disturbance. Inability to make this recognition has led to absurd misconceptions and misrepresentations of the views of those who hold that the topography of the land is essentially the result of a process of sculpture.

It is evident that in a landscape which has been the scene of so prolonged a series of geological vicissitudes, its several topographical features may differ widely from each other in antiquity, and that the relative order of appearance of these features may have little or no connection with the geological age of their component rocks. A mountain, for example, which consists mainly of the most ancient formations may nevertheless have been upheaved only at a comparatively late period. Thus, the Alps, as they now appear, though their central ranges are composed of primitive materials, were finally uplifted in Tertiary time. Further, the same feature may belong to more than one period of geological history. A mountain-chain like the Alps may have undergone elevation again and again during the ages of the past. A hill isolated or a valley excavated during one remote period may be buried and preserved under younger formations, and may in far later times be uncovered and restored to the present topography of the land by the progress

of denudation. The face of the land becomes to the geologist a kind of palimpsest on which the records of a long succession of revolutions have been inscribed, effaced, and written over once more. And it is the fascination of the task of its decipherment which constitutes one of the great charms in the study of the origin of scenery.

Let me conclude this summary by briefly sketching what appears to me to have been the history of the superficial changes of a country. The bed of the sea, which we may suppose to be a plain of erosion where a land area once stood, is raised above the waves. From a point or line where the elevation of the new land is greatest, the ground slopes down to the sea-level. Perhaps the elevatory force shows itself in the upheaval of one or more parallel folds, or it may culminate in the upthrust of some great mountain ridge along the axis of the raised tract. But whether uplifted in one great dome-shaped mass, or in a long ridge, or in several ridges with parallel dividing hollows, the whole surface of the new land—its gentle slopes or abrupt declivities, its long broad summits or angular crests, its dislocated crags or smooth undulations—is at once attacked by the various denuding agents. As they first rise into land, these features are scoured away by the waves and tidal currents within whose reach they come. As they ascend above sea-level, they at once become a prey to the disintegrating action of the atmospheric forces. Every hollow on their surface offers itself as a channel by which the drainage may be conveyed to the sea. Even if the submarine plain were upraised without disturbance, such results would follow. Its surface would not be a mere dead level, and rain falling upon it would necessarily flow off from the highest parts down to the shores. The drainage gathers into runnels, which, widening into brooks and rivers, at once begin to carve out their channels, or the moisture falls in the form of snow, and then glaciers take shape and, carrying off the drainage of the snow-fields, grind paths for themselves from the high grounds

to the shore. Thus begins the scooping out of a system of valleys that diverge from the higher parts of the rising land. These depressions are slowly dug deeper and wider, until at last the ancient elevated sea-bed is worn into a system of hills and mountains, valleys and glens. The land thus modelled may remain stationary for a vast interval, but it is all the while undergoing continual degradation of its surface. In the end it may once more be worn down to the sea-level. Movements of subsidence may afterwards carry it down far below that level and allow it to be covered over with newer deposits. The sites of its highest ridges or loftiest mountains may thus be buried beneath piles of their own ruin, as they slowly sink under the sea. If, now, there should once more be a renewed elevation of this area into dry land, these later accumulations would be exposed to a similar waste, and a new series of denudations would be begun by the air, rains, streams, ice, and the sea, new valleys would be excavated, and new hills would be left standing out from them. By such a process of ceaseless change, thus summarily stated, carried on during many successive geological periods, the present scenery of our country appears to have been produced.

In the succeeding chapters, I propose to attempt to trace in some detail the history of the process of topographical evolution as manifested in the hills and valleys of Scotland. Though we may understand the general character of such a series of changes in nature, it is often by no means easy to follow out the details of successive stages in the development of a landscape which were completed so long ago that their memorials are now obscure and incomplete. Such, however, is the task now before us. In entering upon it, I feel that it is possible, in the meanwhile, merely to grope the way. The only light which can be taken with us is that of the various geological processes as they are now at work. Without its help all would be utter darkness, but under its direction we may be enabled to advance some little way. I shall

endeavour to lay before the reader the facts on which each inference is based, that he may judge how far there is actual evidence from which to restore in imagination certain ancient conditions of the country.

Two methods of treatment are here open to us, each of which possesses its peculiar advantages. We may discuss the subject entirely from the geological point of view, arranging all the facts of the same kind in one division, without reference to their distribution in the country. This method is undoubtedly preferable for those who, having no personal acquaintance with Scotland, are chiefly desirous to see all the topographical details of the same kind marshalled together and connected with the conclusions in science to which they lead. On the other hand, we may consider the question from the geographical point of view, taking each well-marked district or region, and trying to work out the history of its scenery. This plan is probably most useful for those who purpose themselves to study the problem on the ground, and to test by actual observation the conclusions to which their assent is asked. While this volume will, I trust, be of service to both classes of readers, I am more especially anxious that it should be made as available as possible to those who mean to use it as a handbook to the scenery which it professes to discuss. I shall therefore follow mainly the geographical method.

Scotland naturally divides itself into three great belts of country, each of which is marked by its own peculiarities of geological structure and of external configuration: (1) The Highlands, including also the western and northern Islands; (2) the Southern Uplands, or the broad belt of high pastoral ground that stretches from St. Abb's Head to the Irish Sea; and (3) the Midland Valley, or wide central lowland which lies between the two other regions, and includes the lower parts of the basins of the Tay, Forth, and Clyde. My account of the Highlands will necessarily be the longest, not only because that region is the largest of the three, but because its geological

structure and scenic features are more varied, and because the principles established for the elucidation of topographical details in that part of the country do not require to be repeated and enforced for the other districts.

The maps which accompany this volume are meant to illustrate the close connection which exists between the topography and scenery of the country on the one hand, and its geological structure on the other. In Plate I., where the broad distribution of the high and low ground is represented, the position and relative areas of the three great belts above referred to can be seen at a glance. In Plate II. the surface features in their relation to the vegetation of the country are represented. It will there be observed how closely the heaths and rough pasture-lands keep to the hilly ground, how the arable tracts are mainly confined to the valleys and lowlands, and how the forests and strips of plantation are chiefly to be met with along the valleys and lochs of the Highlands.

The meaning of this distribution of surface features becomes at once clear from an inspection of the two geological maps (Plates III. and IV.). Plate III., wherein the distribution of the various geological formations is represented, shows that the Highlands lie mainly on crystalline schists and eruptive rocks; that the Southern Uplands consist almost wholly of Silurian sedimentary materials; and that the Midland Valley, underlain chiefly by the Old Red Sandstone and Carboniferous systems, is varied by its two parallel ranges of northern and southern heights, built up mainly of ancient volcanic lavas and ashes. Lastly, an examination of the map of the general glaciation of the country (Plate IV.) will explain further why the valleys and lowlands have been so much more brought into cultivation than the rest of the country, for it shows that these tracts are in great measure overspread with drift-deposits, which supply a deeper and more fertile soil than what is furnished by the bare rocks of the other and especially the more elevated districts.

PART II.—THE HIGHLANDS

CHAPTER VI

PHYSICAL FEATURES AND GEOLOGICAL STRUCTURE

Physical Features

The Highlands, for convenience of description, are here regarded as embracing all that part of the country which lies west and north of a line drawn along the Firth of Clyde, and thence diagonally in a north-easterly direction from the mouth of the river Clyde to the east coast at Stonehaven. Nearly the whole of this region is high ground, deeply trenched with valleys, and penetrated, particularly on the west side, by long arms of the sea. The only considerable area of lowland lies in the north-eastern counties, embracing the eastern part of Aberdeenshire and the northern parts of Banff, Elgin, and Nairn. Along both sides of the Moray Firth a strip of lower land intervenes between the foot of the hills and the sea, while farther north the county of Caithness is one wide plain, which is prolonged into the Orkney Islands. These low grounds neither geologically nor historically form part of the Highlands; but they may for our present purpose be included therewith.

Seen from the south, the front or edge of the Highlands presents a well-defined chain of hills, which rise abruptly from the plains of the Lowlands. This is best observed in Strathmore, but it is also conspicuous in the estuary of the Clyde, where the low hills of Renfrewshire and Ayrshire contrast well with the broken line of rugged mountains to the north (Fig. 27).

FIG. 27.—View of the Highland table-land from above Gourock, on the Clyde.

Viewed from any of the islands of the chain of the Inner Hebrides, the Highlands along their western sea-front appear to stretch as a vast rampart, indented by many winding sea-lochs, and rising up to a singularly uniform general level, which, sinking here and there into glens and straths, allows glimpses to be had of still higher summits in the interior beyond. The northern margin is hardly less striking when looked at from the Moray Firth, or from the plains of Caithness or Orkney.

From a commanding summit in their interior, the Highlands are seen to differ from any mountain-chain such as the Alps, not merely in their inferior elevation, but essentially in their configuration and structure. They are made up of a succession of more or less nearly parallel confluent ridges, which have, on the whole, a trend from north-east to south-west. These ridges, separated by longitudinal valleys, are furrowed by transverse valleys, and the portions thus isolated rise into what are termed mountains. But all these loftier eminences are only higher parts of ridges along which their geological structure is prolonged. It is singular to observe how the general average of level of the summits of the ridges is maintained. From some points of view a mountain may appear to tower above all the surrounding country; but if it is looked at from a sufficient distance to take in its environment, it is found not to rise much above the general uniformity of elevation. This subject will be more fully treated in Chapter VII. Throughout the Highlands there are no gigantic dominant masses, no central chain of heights like a range of Alps, that must obviously be due to some special terrestrial disturbance. A few apparent exceptions to this statement rise along the western sea-board of Sutherland, in Skye, and elsewhere; but an examination of their structure at once explains the reason of their prominence, and confirms the rule.

The Highlands are separated into two completely disconnected and in some respects contrasted regions by the remarkable line of the Great Glen, which runs from the Linnhe Loch

to Inverness. In the north-western portion, the highest ground rises along the west coast, mounting steeply from the sea to an average height of perhaps between 2000 and 3000 feet, but occasionally throwing up a summit a thousand feet higher. The watershed consequently keeps close to the Atlantic sea-board; indeed, in some places it is not more than a mile and a half distant from the beach. From these heights, which catch the first downpour of the western rains, the ground falls eastwards, but with numerous heights that prolong the mountainous character to the edge of the North Sea and the line of the Great Glen. The best conception of the difference in the general level on the two sides of the watershed may be obtained by observing the contrast between the lengths of the streams. On the western side the drainage is poured into the Atlantic Ocean after flowing only a few miles, while on the eastern side it has to run six or eight times the distance. At the head of Loch Nevis, the western stream is only three miles long; that which starts from the eastern side has a course of some eighteen miles to the Great Glen. Throughout this northern or north-western region, a general ruggedness of feature characterises the scenery, betokening even at a distance the wide extent of those types of schist to which the topography is due. Along the western coast of Sutherland and Ross some singular groups of cones and stacks (to be afterwards referred to), and farther south the terraced plateaux and abrupt conical hills of Skye, Rum, and Mull, vary the prevalent forms of the ground. The main valleys run for the most part in a north-west and south-east direction, and this is also generally true of the sea-lochs.

The south-eastern region of the Highlands, or that which lies east of the Great Glen, is, on the whole, more diversified in geological structure, and presents somewhat greater contrasts of scenery. In the first place, its valleys chiefly run in a south-west and north-east direction, and so also do most of its lakes and sea-lochs. This feature is strikingly exhibited in the western part of Argyllshire. But there are also numerous and

important transverse valleys, of which that of the Garry and Tay is the most conspicuous example. Again, the watershed in this region is arranged somewhat differently. It first strikes eastward round the head of Loch Laggan and then swings southward, pursuing a sinuous course till it emerges from the Highlands on the east side of Loch Lomond. But the westward flowing streams are still short, while those that run north-east and east have long courses and drain wide tracts of high ground. The Tay, in particular, pours a larger body of water into the sea than any other river in Britain.

Moreover, the occurrence of many bosses of granite and other eruptive rocks gives rise to various interruptions in the monotonous scenery of the crystalline schists which constitute the greater part of the south-eastern region of the Highlands. A marked contrast may be traced between the configuration of the north-eastern and that of other parts of this region. Towards the north-east, the Grampians rise into wide flat-topped heights or elevated moors often over 3000, sometimes exceeding even 4000 feet in height, and bounded by steep declivities, or not infrequently by precipices (Figs. 12 and 54). Seen from an eminence on their surface, these plateaux look like fragments of one original broad table-land, which has been trenched into segments by the formation of the transverse and longitudinal valleys (Fig. 39). Farther to the south-west, in Perthshire, Inverness-shire, and Argyllshire, they give place to the ordinary hummocky, crested ridges of Highland scenery, some summits on which, however, exceed 4000 feet in elevation. To the probable meaning of this transition from broad flat-topped heights to narrow crests and isolated peaks, allusion will be made in Chapter IX.

The general surface of the Highlands is rugged. The rocks project in innumerable bosses and crags, which roughen the sides and crests of the ridges. The forms and colours of these roughnesses mainly depend on the nature of the rock underneath. Where the latter is hard and jointed, weathering into

large quadrangular blocks, the hills are more especially distinguished for the gnarled bossy character of their declivities, as may be seen in Ben Ledi and the chain of heights to the north-east of it, formed of massive grits and mica-schists. Where, on the other hand, the rock decays into smaller debris, the hills are apt to assume smoother contours, as in the slate hills that run from the Kyles of Bute to Loch Lomond. Wherever any mass of rock occurs, differing much from those around it in its power of resisting decomposition, it affects the scenery, rising into a prominence where it is durable, or sinking into lower ground where it is not. This relation between relative destructibility and external configuration may be regarded as the general law that has in all parts of the world chiefly determined the present topography of the land. Fuller reference to it and further illustrations of its importance in the elucidation of Scottish scenery will appear in the sequel.

Besides the principal tracts of low ground in the Highlands already referred to, there occur numerous long but narrow strips of flat land in the more important valleys. Each valley is usually provided with a floor of detritus, which, spread out between the bases of the bounding hills, has been levelled into meadow-land by the rivers, and furnishes, as a rule, nearly the only arable ground in each district.

The islands that fringe the Highlands on the western side present two strongly contrasted types of scenery. The Outer Hebrides, from the Butt of Lewis to Barra Head, resemble portions of the west of Sutherland, with which they are in geological structure identical, and no doubt represent a very ancient range of hills which rose along the western border of Europe before the British Isles were separated from the continent. Coll, Tiree, and the islands which continue seawards the south-western portion of Argyllshire, are merely disconnected parts of the adjacent mainland, having the same rocks and the same kind of scenery. But the group of islands known as the Inner Hebrides, of which the chief are Skye,

Mull, Rum, Eigg, and Canna, belong to a totally different order. They are in large measure composed of terraced, flat-topped basalt hills with rich green slopes and long level lines of brown crag (Figs. 22, 23, 49, 64, 65). The regularity of their forms stands in strong contrast to the ruggedness of the true Highland mountains; and this contrast suffices to show that, throughout the area of these islands, the ordinary type of Highland rocks is replaced by others of a totally distinct kind.

The Orkney Islands are merely a northward prolongation of Caithness, and, together with that county, ought not in strictness to be considered with the Highlands. The whole of that region, from the southern edge of Caithness to the most northerly headland of the Orkneys, is composed of a low flat table-land or plain of Old Red Sandstone, out of which the islands have been cut. The same plain is prolonged into the southern part of the Shetland Islands, but the greater part of that group consists of rocks like those of the Highlands, and repeats on a minor scale many of the characteristics of Highland scenery, with the additional peculiarity and attractiveness which are given by the singular forms into which the rocks have been cut by the Atlantic breakers.

Geological Structure

The line already referred to as drawn from Stonehaven on the coast of Kincardine in a south-western direction across Forfarshire, Perthshire, Stirlingshire, and Dumbartonshire, to the Firth of Clyde, divides the Highlands from the broad Midland Valley drained by the Tay, Forth, and Clyde. It is a well-marked geological line, for it coincides with the boundary between the old crumpled gneisses and schists of the northern half of the kingdom and the conglomerates, red sandstones, and volcanic rocks of the broad central lowland. It marks the position of one of the great dislocations of our islands. The rocks on its southern side have been broken through and

placed on edge against the flank of those on the north side. Thus it is both a good geological line and a well-marked limit for two very different types of scenery. To the south-east lie the gently undulating hills and wide agricultural plains of the Old Red Sandstone; to the north-west a sea of mountains rolls away to Cape Wrath in wave after wave of gneiss, schist, quartzite, granite, and other crystalline masses.

This mountainous tract, forming the Highlands of Scotland, is bordered on the north-east with a belt of Old Red Sandstone

FIG. 28.—Rounded bossy surface of Lewisian gneiss, Loch Inchard.

which underlies most of the strip of fertile lowland that runs round the northern margin of the Highlands from the coast of Banffshire to the far headlands of Caithness. Though now mostly stripped off from the continuation of the same low grounds eastward into Aberdeenshire, the Old Red Sandstone is left in many little patches, and not improbably at one time covered most or all of these plains, even as far south as Aberdeen, if not quite to the broad tract of the same formation in Kincardineshire. On the west side of the Highlands lies the broken chain of the Inner Hebrides, with its green

terraced hills of Tertiary lavas. Considered broadly, therefore, the area of the Highlands may be looked upon as a kind of island of ancient crystalline masses set in a sea of younger formations. I shall now proceed to describe its component rocks and their distinctive outer features, beginning with the oldest, and will then give an account of the manner in which they have been arranged.

The oldest rock of the Highlands is a massive gneiss, called Lewisian, from its development in the Isle of Lewis, and representative of that ancient series which is grouped under the name of Archæan. It varies considerably in texture and colour. Some portions are structureless like a granite, others are finely schistose, and between these two extremes every gradation of typical gneiss-structures may be found. It presents likewise considerable variety of composition, some parts being acid, others basic. It includes many veins of pegmatite and dykes of diabase, as well as seams of dark hornblende and hornblendic gneiss, which doubtless represent what were once intruded veins. Almost everywhere it is marked by great toughness and durability. There could have been no fitter material for the foundation-stone on which the geological structure of Britain should be built up.

As regards its origin, we may speculate without any very solid basis on which to build. Certainly the nearest analogies among younger rocks whose history remains tolerably clear are to be found in the deep-seated portions of large eruptive masses, such as granites and "greenstones." In some places, as in Gareloch, Loch Carron, and Glenelg, it includes certain schists and limestones which no doubt represent a sedimentary series into which the various members of the "fundamental complex" were probably intruded. The intrusion took place, we may believe, under a considerable depth of the terrestrial crust, and consisted of many successive invasions of both acid and basic material, followed by the subsequent uprise of still other rocks in the form of dykes. If any of these igneous

rocks ever communicated with the surface in volcanic discharges, no trace of their superficial manifestations has yet been detected. Only their deep-seated portions have been preserved.

The areas occupied by the Lewisian gneiss are readily recognisable even at some distance by their singularity of contour. They do not occupy much space in the general area of the Highlands, being, indeed, confined, so far as we yet know, to the north-western counties. They include, as their main development, the long chain of the Outer Hebrides. On the mainland, they run as a broken fringe from Cape Wrath to the Island of Raasay, coming out boldly to the Atlantic in the northern half, but throughout the southern portion retiring towards the heads of the bays and sea-lochs, and even stretching inland to the upper end of Loch Maree. But to the east of a line of dislocation to which more special reference will be made a few pages further on, vast slices of the same ancient formation, sometimes many square miles in extent, have been torn off from the main and now deeply-buried mass of the gneiss, and have been carried up on successive "thrust-planes," so as to appear intercalated among younger formations. Such disrupted slices appear again and again among the mountains in Western Sutherland and Ross, as well as in the part of Inverness-shire that lies between the Atlantic sea-board and the line of the Great Glen. Similar masses have not yet been certainly detected to the east of that line.

Whether the traveller approaches a tract of Lewisian gneiss from the sea or from the land, on the west side of the great belt of dislocated ground just referred to, he can hardly fail to remark its curious peculiarities of outline. If he looks at it from the western or Atlantic side, as, for instance, in sailing up one of the fjords (Fig. 28), or coasting along the western sea-board of Sutherland, he sees the land rising out of the water in bare rounded domes of rock, crowded behind and above each other as far as the eye can follow them. Not a tree nor a bush casts a shadow over these wastes of barren rock. It might at first

be supposed that even heather had been unable to find a foothold on them. Grey, rugged, and verdureless, they look as if they had but recently been thrust up from beneath the waves, and as if the kindly hand of Nature had not yet had time to clothe them with her livery of green. Strange, however, as this scenery appears when viewed from a distance, it becomes even stranger when we enter into it, and more especially when

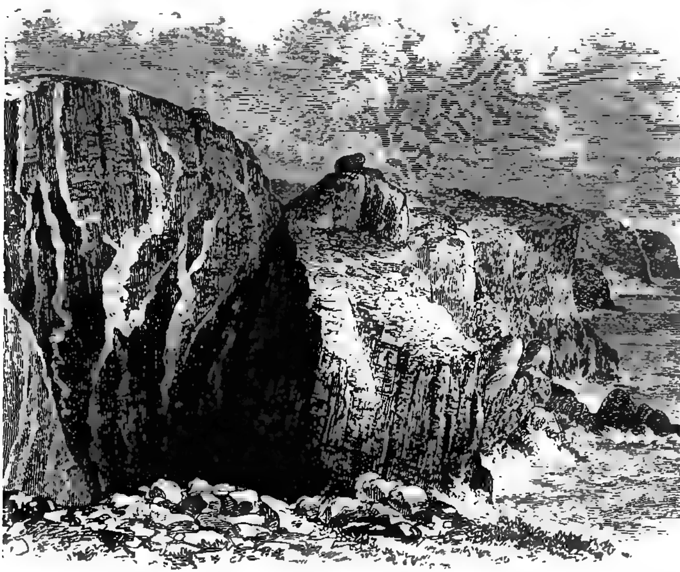

FIG. 29.—Cliffs of Lewisian gneiss, with pink pegmatite veins, Cape Wrath.

we climb one of its more prominent heights and look down upon many square miles of its extent. The whole landscape is one wide expanse of smoothed and rounded bosses and ridges of bare rock, which, uniting and then separating, enclose innumerable little tarns (Fig. 71). There are no definite lines of hill and valley; the country consists, in fact, of a seemingly inextricable labyrinth of hills and valleys which, on the whole, do not rise much above nor sink much below a general average

level. Over this region of naked rock, with all its bareness and sterility, there is a general absence of peaks or prominent crags. The domes and ridges present everywhere a rounded, flowing outline, which has only here and there been partially defaced by the action of the weather.

These contours, so characteristic of the old gneiss in the north-west of Scotland, appear, from evidence which will be adduced immediately, to be for the most part of extreme antiquity, though there can be no doubt that they have been modified by the ice of the Glacial Period. The whole surface of the gneiss-ground has obviously been worn smooth by ice. The polished, striated, and grooved surfaces left by the ice are still everywhere to be seen, and huge blocks of rock scattered all over the ground, and sometimes poised on the very summits of the rounded rock-domes, remain to complete the proofs of former glacial action (Figs. 73, 75, 76). It is only here and there, where the ice-worn surface has been broken up, that we can see how the gneiss yields to the present conditions of weathering. One of the best localities for observing its aspect under these conditions is the range of cliffs to the south of Cape Wrath. Bearing there the full brunt of every storm that sweeps across the Atlantic, the rock is peculiarly exposed to disintegration. Every weak part of its framework, discovered by the furious winds, fierce rains, and surging breakers of that desolate and iron-bound coast, is hollowed out into cleft or gully, tunnel or cave, while the harder parts protrude in massive buttresses, or tower aloft in fantastic columns. Its huge veins of pink pegmatite seem to writhe up the face of the dark cliffs like the sinews of some antique statue (Fig. 29).

But by a rare and fortunate accident we are in possession of a fragment of a land-surface of the extremest antiquity, in which certain topographical forms of the Lewisian gneiss have been preserved. The geological interval of time between the production of the gneiss and that of the next succeeding formation is represented by a vast gap in the geological record.

If the gneiss as now visible belongs to some of the deep-seated portions of igneous eruptions, it must have consolidated beneath a depth of rock long since removed. An attentive examination of it, where it passes under the next overlying formation (Torridon sandstone), discloses the important fact that the removal of this thick cover of superincumbent rock was completed before that formation began to be laid down. The gneiss territory must have been exposed for many ages to extensive denudation, as the result of which probably many hundreds or thousands of feet of rock were worn away from it. We learn further that in process of time the region was carved into hills and valleys, wherein the once deeply-buried parts of the gneiss formed the surface-features. The topography thus revealed is the oldest known fragment of Europe. It goes back far beyond the age of the earliest of our fossiliferous formations.

This primeval assemblage of hills and hollows has been preserved by having been buried under the red sandstones and conglomerates to be immediately described, and is now exposed again to view in consequence of the removal of these overlying deposits by denudation. It is best seen between Loch Maree and Dundonald, but smaller fragments of it may be detected in Loch Torridon, in Gareloch, and at the back of Quinaig in Assynt (Fig. 30). Some of the gneiss mountains were 3000 feet high, as may be observed in A'Mhaighdean, a little to the north-east of Ben Slioch, on Loch Maree.

This ancient land had a remarkably uneven surface, on which the Torridon sandstone was deposited. Here and there the gneiss, as it emerges from underneath that formation, is seen to have been worn into rounded hummocks that resemble the ice-worn bosses of later times. In other places, its surface is more angular, projecting upwards in crags and pinnacles into the overlying sandstones, while the latter descend into clefts and winding crannies of the gneiss, as may be seen on the flanks of Slioch, above Loch Maree.

Above the venerable Lewisian gneiss, the next member of the series of geological formations consists of dark-reddish and purplish-brown sandstone and conglomerate, which lie with a marked unconformability upon the gneiss. These stratified rocks, though they had not yielded any fossils, were called Cambrian by Murchison, being regarded by him as probably equivalents of the oldest sedimentary formations of Wales. But in recent years they have been proved to be of much higher

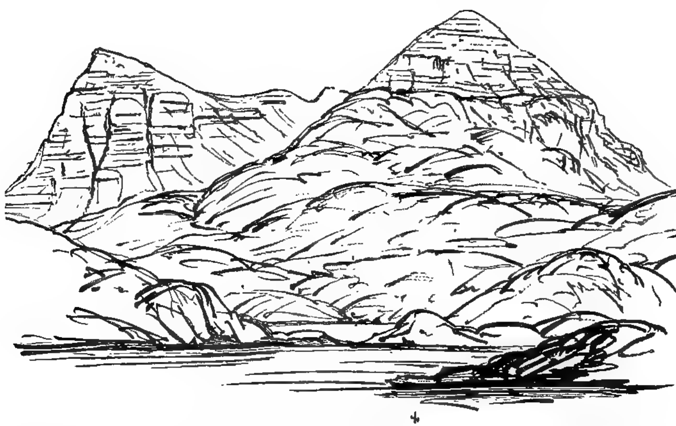

FIG. 30.—View of Quinaig, Sutherland. The gneiss forms the lower ground and rises in the right hand part of the mountain into a hill some 700 feet high, which is capped and still partially surrounded by nearly flat Torridonian sandstone and conglomerate.

antiquity, inasmuch as they have been found to be unconformably overlain by the very oldest division of the Cambrian system. They remain, therefore, among the pre-Cambrian rocks, and are distinguished by the name of Torridonian, from their copious development around Loch Torridon, in the west of Ross-shire. Reference has already been made to the enormous interval of time that separated them from the epoch of the Lewisian gneiss. The gneiss was in truth just as gnarled and venerable-looking a rock when these sandstones were laid down upon it as it is now.

The Torridon sandstone was deposited during a time of subsidence, when the primeval gneiss-land above referred to gradually sank under water. We may walk along the old pebbly shore-lines of that ancient time, and mark how sheet after sheet of gravel and sand were spread out there, and were carried down under ever-increasing accumulations of similar material.

Between the aspect of the tracts occupied by the Torridon sandstones and that of the ancient gneiss there is a contrast more abrupt and impressive than almost any other in Highland landscape. So sharp is the line of demarcation between the two rocks, that their respective areas can be accurately followed by the eye even at a distance of several miles. The tumbled sea of bare gneiss rolls, as it were, under the red sandstones, which in nearly horizontal beds rise into isolated and strangely-shaped mountains, sometimes to a height of 3400 feet above the sea (Figs. 30, 31, 60, 61). As the ground mounts into these eminences, the covering of herbage grows more and more scant, but the same terraced bars of rock, which begin where the sandstone first appears, continue to stand out more and more clearly until they form naked precipices, where, as seen from below, there does not seem to be room even for a tuft of heather or an alpine plant. The parallel bars that mark the successive strata can be traced with the eye to the far summits, and from crest and to crest of these vast solitary cones which, standing alone on their platform of gneiss, remind one rather of rude colossal pyramids than of the free bold sweep of crag and slope so characteristic of other mountains. Moreover, by the influence of intersecting joints the escarpments of these level strata have been split into huge quadrangular columns and buttresses, which project from the front of the mountains and rise along the sky-line in such an array as to add much to the general architectural effect of the stratification.

The depth of these sandstones must amount to eight or ten thousand feet. Even in a single mountain, such as Ben

Leagach in Glen Torridon (Fig. 31), a thickness of more than 3400 feet can be taken in at a glance of the eye from base to summit. Yet when this massive formation is followed along the strip of country in the west of the counties of Ross and Sutherland, where it occurs, it is found to thin out and disappear in a most remarkable way. No doubt it was originally of somewhat unequal thickness, being laid down upon an uneven platform of gneiss, but its rapid attenuation is probably referable to extensive and unequal denudation before the next group of rocks was deposited. The huge pyramidal mountains into which it rises are, in truth, colossal monuments of denudation, to which fuller reference will be made in a later chapter.

Above the red sandstones, but separated from them by another great geological hiatus, represented by a strong unconformability, for the filling up of which there is as yet no evidence, lies an interesting series of strata, which extends from the Kyle of Durness and the mouth of Loch Eribol to the west side of Sleat, in Skye. The lowest member of this series is a group of white quartzites, then come some dolomitic shales, followed by limestones and dolomites, the whole having a thickness of at least 2000 feet in the Durness district. Certain bands of the quartzites are crowded with the burrows of marine worms, of which there seem to have been several varieties. The dolomitic shales include some species of the trilobitic genus *Olenellus*, which is taken to characterise the lowest subdivision of the Cambrian system. The limestones have yielded a much larger variety of fossils, which indicate higher parts of that system, or even perhaps the very base of the overlying Silurian rocks. The general assemblage of organisms in these Cambrian strata of North-west Scotland resembles that of the oldest Palæozoic series of Canada, rather than that of the rest of Britain. The quartzites and limestones of Sutherland and Ross possess the utmost importance in the geological structure of the Highlands, seeing that, by furnishing a

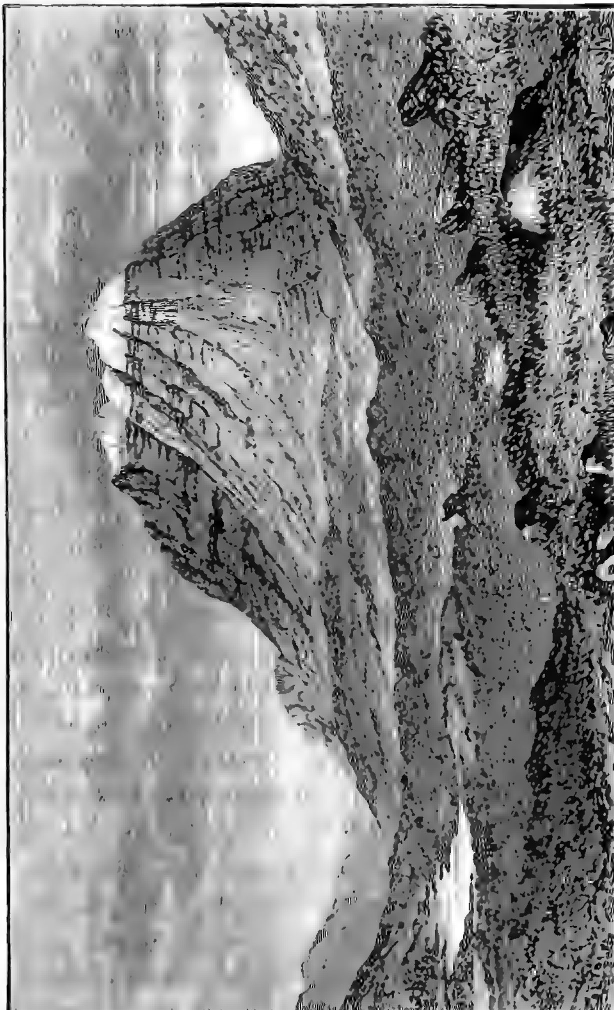

FIG. 31.—Ben Leagach, Glen Torridon. A mountain of nearly horizontal red (Torridonian) sandstone, capped with white quartzite.

definite and recognisable stratigraphical horizon, they supply a clue to the complicated geological structure and relative ages of the rocks of the whole Highland region.

What was the next formation that supervened on the top of the limestone and dolomite has not been discovered. We can hardly suppose that no representatives of the Silurian system, so thickly developed in the south of Scotland, were laid down. On the contrary, we may infer that the limestones were not improbably buried under deep accumulations of later sediments, though these cannot now be satisfactorily recognised, so great have been the geological changes of the region.

Along the southern margin of the Highlands, wedged in between the crystalline rocks and the faulted boundary of the Old Red Sandstone, the Geological Survey has detected a zone of black slates, radiolarian cherts, agglomerates, tuffs, and diabase-lavas with ellipsoidal or "pillow" structure, which may be equivalent in stratigraphical position to a closely similar group of Arenig and Lower Llandeilo age in the Southern Uplands of Scotland. If this conjecture be confirmed, it would appear that some at least of the movements to which the geological structure of the Highlands is due, took place after the deposition of the oldest Silurian strata, and that these strata, to some as yet unknown extent, enter into the composition of the Highland mountains.[1]

The geological structure of the west of Sutherland and Ross-shire has given rise to much discussion among geologists. It would be foreign to my present object to enter into the historical aspects of this discussion. Reference, however, may

[1] This interesting discovery has been made by my colleagues of the Geological Survey, Mr. Barrow in Forfarshire and Kincardineshire, Mr. Clough between Loch Lomond and Callander, and Mr. Gunn in Arran, while Mr. Peach has visited all the localities and has contributed to the investigation of them the assistance of his intimate knowledge of the Arenig and Llandeilo rocks of the south of Scotland. We have found what appear to be the same rocks well developed along the borders of the schists near Pomeroy in the north of Ireland. (See *Annual Reports of Geological Survey* for 1893, 1895, 1896, and 1899.)

be made to the views propounded by the late Sir Roderick Murchison, which, in common with the great majority of geologists, I adopted, and which were expounded in the first edition of this volume. According to these views, the fossiliferous strata of Durness and Eribol pass conformably under, and are followed by, a thick series of schists, which, in constantly repeated folds, constitute the greater part of the Highlands. The evidence of an unbroken sequence, from the base of the quartzites up into the overlying schists, seems in many places to be so unmistakable that the sections of the north-western counties were held to prove the whole of the

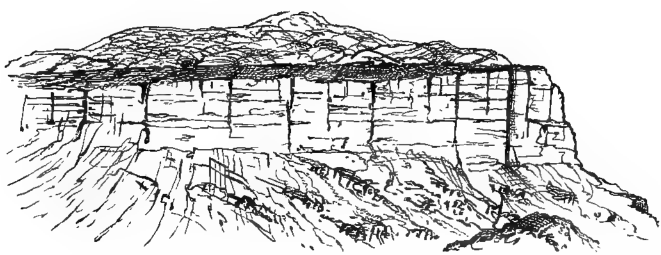

FIG. 32.—View of the north front of Bein na' Mhuinidh, Loch Maree. The lower slopes lie upon unmoved Lewisian gneiss, above which a thick unconformable zone of nearly flat Torridon sandstone forms a line of precipice. This sandstone is followed unconformably by Cambrian quartzite and dolomite, represented as a dark zone in the sketch, while the uppermost band of the mountain includes a cake of the old gneiss pushed over the other rocks by a thrust. (See Fig. 33.)

crystalline schists of the Highlands to be demonstrably younger than the limestones of Durness.

This conclusion was at first accepted and afterwards denied by the late Professor Nicol of Aberdeen, who in his later papers contended that what were called by Murchison and his associates the younger schists were really the Archæan gneiss brought up by great displacements. The complete divergence in structure and lie, however, between these schists and the true old gneiss, as well as the apparent conformable succession from the limestones up into the schists, were generally regarded

as irreconcilable with the explanation proposed by Nicol, and Murchison's views continued to maintain their hold.

Various writers had meanwhile proposed other solutions of the difficulties; but it was not until the year 1884 that, the ground having been studied in great detail, conclusions were arrived at independently by the Geological Survey and Professor Lapworth, which have at last given the key to the problem.[1] Nicol was found to have been undoubtedly right in maintaining that the old gneiss is brought up again to the east of the limestones, but he failed to account for the origin of the so-called younger gneisses, in which the planes of foliation conform to the general dip of the underlying limestones, shales, and quartzites. It now appears that, by the extraordinary series of upthrusts already referred to, portions of the old gneiss have not only been forced from beneath thousands of feet of strata under which they lay buried, but have been pushed bodily over these strata, sometimes for a distance of at least ten miles (Figs. 32, 33). Where the masses of gneiss, thus torn off and driven westwards, have been of sufficient thickness, they have retained much of their old structure. They appear in vertical beds with their pegmatites and hornblendic bands, and repose upon gently inclined limestones, shales, and quartzites. But along the upper and under surfaces of such displaced masses, the rock has been subjected to such intense pressure and shearing as it moved along that its component minerals have been crushed and drawn out in the direction of movement, so as to give the rock a fissile, streaky, or schistose structure. Where the masses of gneiss have been comparatively thin this rearrangement has been effected throughout their whole extent; they have lost their former vertical foliation and have acquired a new one, the surfaces of which are in general parallel with the planes of the thrust

[1] Report by B. N. Peach and J. Horne, *Nature*, 1884, p. 29; and fuller memoir in *Quart. Journ. Geol. Soc.* xliv. (1888), p. 378; Lapworth, *Proc. Geologists' Association*, viii. (1884), p. 438.

movements, and with the bedding of the Cambrian strata. The Torridon sandstones and conglomerates have likewise been caught up in the same gigantic displacements, and they too have undergone the most extraordinary transformation into mica-schist and other foliated masses, the quartz pebbles of the conglomerates being drawn out but still recognisable. This remarkable transformation is represented in the woodcuts upon p. 135. Fig. 34 shows the ordinary character of the unaltered sandstone, Fig. 35 the effects of crushing upon that rock, where it has been converted into a true schist. The quartzites also, where they have been subjected

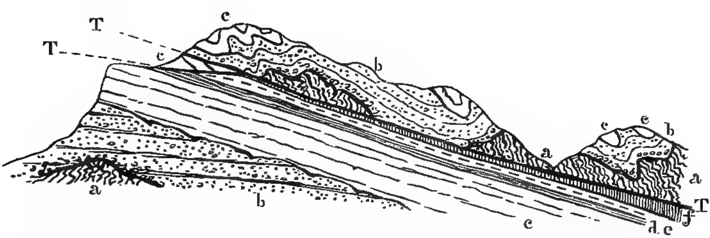

FIG. 33.—Section from north to south across the mountain shown in Fig. 32. *aa*, Lewisian gneiss. *bb*, Torridon sandstone. *cc*, Cambrian quartzite. *d*, "Fucoid beds" with *Olenellus* zone. *e*, Serpulite grit. *f*, Dolomite (Cambrian). *TT*, Thrust-planes.

to movement of the same kind, have assumed a similar foliated structure. In short, the effect of the internal crushing and rearrangement of the rocks under the enormous stresses to which they were subjected during the process of upthrust has been to superinduce upon them all a general schistose structure, the planes of which lie parallel with the direction of movement. Moreover, the dislocations or thrust-planes by which slice after slice of the underlying rocks has been torn off and driven upwards are generally inclined at angles not markedly different from those of the bedding of the Cambrian and Torridonian strata (see Fig. 33), so that both on the large and on the minute scale a singular parallelism has been produced

between the divisional planes of the upthrust masses and those of the sedimentary series upon which they lie.

Here then is the explanation of the apparent conformable sequence of the younger schists which so deceived Murchison and other geologists. These rocks are not altered sedimentary deposits which follow regularly upon the limestones, as they appeared to be. Whatsoever may have been their original condition, they are now true schists, which acquired their present structure as the result of mechanical movements whereby they have been squeezed up from lower depths to the east. Some portions of them are undoubtedly metamorphosed Lewisian gneiss, some are parts of the Torridon sandstone, and of the Cambrian quartzites, shales, dolomites, and limestones, while some may be crushed sediments and igneous rocks of later date. It remains for future investigation to ascertain how far they may include the transformed representatives of sedimentary deposits that came after the Durness limestones. Excluding the displaced slices of what was no doubt originally Lewisian gneiss —slices which sometimes in Central Ross-shire exceed fifty square miles in area and have a thickness of thousands of feet—we find two prominent and widely diffused types of schist in the great group which, from the Moine in Sutherland, where they were first studied by the Geological Survey, have received the name of "Moine schists." One of these is a muscovite-biotite-gneiss, which not improbably represents an original series of argillaceous sediments that have been intensely metamorphosed and "granitised." The other, which seems to have been a thick series of sandy strata, is a granulitic quartzose flagstone in which the original colour-banding and false-bedding have not been wholly obliterated. In Ross-shire the officers of the Survey have found it possible to map several traceable bands of rock in these schists, and it is not too much to hope that as the mapping advances southward into the wilder regions of Western Inverness-shire, the structure and history of this puzzling group of rocks may be discovered.

Though Murchison and those who followed him were mistaken in regarding these overlying schists as altered Silurian sediments, one great fact for which they contended, that in the North-west Highlands we have evidence of a gigantic metamorphism later than the Cambrian period, is now established upon irrefragable evidence. The vast dislocations, upthrusts and shearing of the rocks, the transformation of the old gneiss into younger overlying gneiss, of Torridon sandstone into mica-schist, of Cambrian quartzites, dolomites, limestones, and diabases into quartz-schists, calcareous and chloritic schists, and the crushing together of all

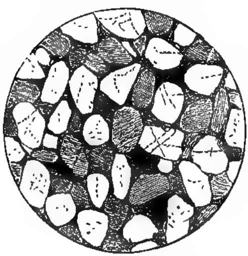

FIG. 34.—Ordinary unaltered red sandstone (Torridonian), Kishorn, Ross-shire (magnified), showing the irregularly-shaped grains of quartz, felspar, etc.

FIG. 35.—Sheared red sandstone, forming now a micaceous schist, Kishorn, Ross-shire. The pebbles are crushed and elongated, and the felspar material has been partly converted into mica.

these rocks into many varieties of crystalline schistose rocks, certainly took place after the Cambrian series of Durness had been formed; and as above suggested, it is even possible that the movements were partly, if not mainly, later than at least the earlier ages of Lower Silurian time (see Section No. 1 on the Geological Map, Plate III.).

How far eastwards into the Highlands these re-formed rocks extend has not yet been accurately determined. There can be no doubt, however, that the same two types of muscovite-biotite-gneiss and granulitic quartzose flagstone

stretch not only to the line of the Great Glen, but over a wide region of the Central Highlands. It may be premature to assert that these eastward extensions of the Sutherland and Ross types belong to the same stratigraphical series; but all the evidence hitherto gathered goes to support that view. As the rocks are followed into the Central and Eastern Highlands, they are found to be associated with and to be replaced by another series of less highly altered schists, which without hesitation can be pronounced to be mainly of sedimentary origin. These include bands of fine pebbly grit and conglomerate, quartzite, limestone, slate, and black graphitic schist. In the region of Loch Awe they are not more altered than the older Palæozoic rocks of the south of Scotland; but for the most part throughout the Highlands they have been more or less metamorphosed, and have in some districts acquired a thoroughly crystalline character. These strata are traversed by abundant sills of epidiorite, diabase and other basic rocks (now largely in the condition of hornblende-schists), as well as by granitic intrusions. They are arranged in numerous parallel arches and troughs (Fig. 36), the long axis of which, with many local variations, runs generally in a direction from south-west to north-east. Over some areas the schists, with their associated quartzites and limestones, are not highly inclined, and their outcrops can be traced like those of ordinary unaltered strata, though elsewhere they have been dislocated and plicated in the most remarkable way.

The foliation or crystalline rearrangement of the component materials of the schists has sometimes been developed along the original bedding-planes, sometimes across them. Occasionally both sets of divisional planes can be detected, as is illustrated in Fig. 37, where the great compression to which the rocks have been subjected is well shown by the way in which the pebbles have been turned round so as to lie parallel with the planes of cleavage. The double series of divisional planes sometimes gives rise to two systems of lines

in the sculpture of a crag or cliff, whereby the rock is split into clefts and slabs in two directions.

That these schistose rocks, constituting the main portion of the Highlands to the east of the line of the Great Glen, are in large measure metamorphosed Palæozoic sediments appears to be in the highest degree probable. They may also include some part of the Torridonian series. Their quartzites and limestones may yet be identified, by means of the evidence of

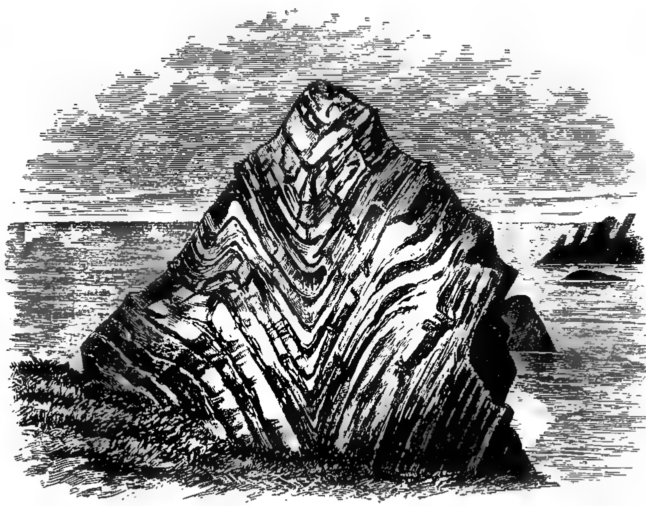

FIG. 36.—Folded phyllite, Shore, east of Banff.

fossils, with the similar rocks of Sutherland and Ross.[1] And, as already suggested, it may eventually be possible to recognise definitely among them the altered representatives of some of the Silurian formations of the Southern Uplands.

From this brief outline, it will be evident that the rocks of

[1] The researches of the Geological Survey furnish some ground for the hope that this identification may be established. Annelid-tubes, like those so abundant in the "piped" Cambrian quartzite of the north-west, have been detected in the quartzites of Perthshire, Islay, and Jura.

the Highlands have undergone enormous disturbance. The subterranean movements that caused the displacements and metamorphism acted in a general direction from south-east to north-west, or from a little south of east to a little north of west. By each upthrust and plication, the rocks were driven forward in that direction. Hence, throughout the Highlands they have a prevalent strike from north-east to south-west. This is the general line of their outcrops, and also of the axes of the arches and troughs into which they have been folded—a structure that has not been without great influence in the subsequent sculpture of the topography. Let me add that, after the great plication and metamorphism, a younger series of granites, diorites, diabases, and other eruptive rocks was injected over the Highland region, and that subsequently, during later commotions, these intrusive masses were themselves partially crushed and converted into schists.

Now it is important for the student of the topography of the Highlands to note that these various terrestrial disturbances mainly preceded the time of the Lower Old Red Sandstone, for that formation, which like a frame encircles the Highlands on the north, east, and south, lies upon the upturned worn edges of the schists, and contains abundant fragments of these rocks. To the Old Red Sandstone itself fuller reference will be made in the following chapter, in connection with the denudation of the region. I will only say here that it appears to have been deposited in great lakes, of which the Scottish Highlands formed part of the boundaries; that it accumulated to a depth of at least 15,000 or 20,000 feet; and that it certainly extended at one time over wide tracts of the Highlands, from which it has since been removed by denudation.

Besides the frame of Old Red Sandstone that partly encloses the region of the Highlands, some other later geological formations likewise form a broken belt on both the

eastern and western sides of the country. These younger deposits are of no great importance as regards the space they occupy, but they possess considerable interest from the information they supply as to the probable condition of the Highland area at certain intervals during the vast lapse of time between the Old Red Sandstone and the present day. A patch of Carboniferous sandstones and shales, with recognisable plant-remains, was found by Professor Judd on the beach of the eastern side of the Sound of Mull. Another little outlier of the same formation has recently been recognised by the Geological Survey at the Pass of Brander. But beyond

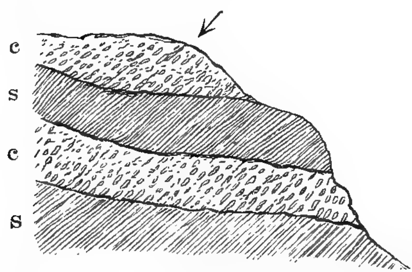

FIG. 37.—Alternating bands of fine conglomerate (*c*) and phyllite (*s*), Shore, Catacol, Isle of Arran. The pebbles in the conglomerate have been moved round and placed with their longer axes in the planes of foliation (indicated by the direction of the arrow), which is oblique to the bedding.

the fact that Carboniferous strata stretched up the west side of Britain as far as the present coast-line of Argyllshire, these widely separated patches do not help in the elucidation of the geological history of the region. No Permian rocks are known to occur within the Highlands. Certain unfossiliferous red deposits, which on some parts of the west coast underlie the Lias, are supposed to be of Triassic age. They consist of sandstones, conglomerates, and breccias, and attain their greatest thickness at Gruinard Bay, on the west coast of Ross-shire, where they must be several hundred feet thick, though generally their thickness does not exceed a few yards. They are found in the islands of Scalpay, Raasay, and Skye, a small

outlier of them coming out from under the volcanic pile of the Cuillin Hills, on the west coast of the last-named island. On the east side of the country, the tract between Elgin, Burghead, and Lossiemouth is occupied by Triassic sandstones enclosing remains of reptiles. A group of strata was formerly exposed at Linksfield, near Elgin, containing fossils which appear to show it to belong to the Rhætic beds at the top of the Trias. But it was almost certainly a mass transported by ice, and indicated that Rhætic strata may exist *in situ* at no great distance under the North Sea.

The Jurassic system is well represented on both sides of the Highlands. Along the east coast of Sutherland, Ross-shire, and Cromarty, good sections are exposed, showing the succession of strata from the Lower Lias up to what may represent the lower part of the Kimmeridge Clay. These rocks are thrown down by powerful faults against the crystalline schists; hence, though now confined to the mere margin of the Highlands, they may once have extended much farther inland. On the west side of the country, Jurassic rocks play a much more important part in the geology, seeing that they occur in many detached areas from the Shiant Isles to the southern shores of Mull. Over much of this region they owe their preservation in great measure to the mass of lavas poured over them in Tertiary time. They have been uncovered, indeed, only at a comparatively recent geological date. They comprise a consecutive series of deposits from the bottom of the Lias up to the Oxford Clay. The Lower, Middle, and Upper Lias consist chiefly of shales and shelly limestones, with some sandstones, well seen along the shores of Skye, and of some of the adjacent islands. The Lower Oolites are made up of sandstones and shales, with some limestones, and are overlain by several hundred feet of an estuarine series of deposits, consisting chiefly of thick white sandstones, below and above which lie shales and shelly limestones. These highest members of the Jurassic series, representing probably

some part of the Oxford Clay, form a prominent feature underneath the basalt terraces of the east side of Skye, Raasay, and Eigg. The sea in which the Lias was deposited stretched southwards across the area of the Inner Hebrides, at least as far as the north of Ireland, for Liassic strata have been preserved under the Tertiary igneous sheets of Antrim. The same sea appears to have extended eastwards into the basin of the Clyde. Possibly the midland valley of Scotland may have been more or less overspread with Jurassic formations (see *postea*, p. 358).

Rocks belonging to the Cretaceous system undoubtedly at one time covered considerable areas on both sides of the Highlands, but they have been entirely stripped off the eastern side, while on the western they have been reduced to a few fragmentary patches, which have no doubt survived because of the overlying sheets of basalt that have protected them. Some greenish sandstones, shown by Professor Judd, from their characteristic fossils, to be the equivalents of the Upper Greensand of the south of England, are found on the south and west coasts of Mull and on the west coast of Argyllshire. They are covered by white sandstones, and these by white chalk and marly beds, which represent the Upper Chalk of England. Enormous numbers of flints and also less abundant fragments of chalk occur in the glacial deposits of the counties bordering the Moray Firth. These transported relics show that the Chalk must once have been in place at no great distance, if indeed it did not actually cover part of Aberdeenshire and the neighbouring counties.

Above the highest Secondary rocks on the west coast come terraced plateaux of basalt, which spread out over wide areas in Skye, Eigg, Mull, and Morven, and form most of the smaller islets of the chain of the Inner Hebrides. These plateaux—possibly fragments of one great volcanic plain—are composed of nearly horizontal sheets of basalt-rocks, columnar, amorphous,

or amygdaloidal, which in Mull attain a thickness of more than 3000 feet.[1] They are prolonged southwards into Antrim, where similar basalts, overlying Secondary strata, cover a large territory. Occasional beds of tuff are intercalated among these lavas, and likewise seams of fine clay or shale, which have preserved the remains of numerous land-plants,

FIG. 38.—Erect coniferous tree in basalt, Gribon, Isle of Mull.

and which with their associated gravelly deposits point to the existence of lakes and streams that gathered on the weathered surfaces of basalt before these were buried under the next lava-deluge. In one instance, a portion of an erect tree, five feet in diameter, still remains within the lava which enveloped it

[1] For illustrations of these Tertiary volcanic rocks, see Figs. 22, 23, 38, 48, 49, 50, 51, 52, 53, 64, 65, 90, and 94 and the Frontispiece.

(Fig. 38).[1] These fossils, besides indicating that the eruptions were sub-aërial, show, on comparison with those elsewhere found among older Tertiary strata, that they probably belong to what is now called the Oligocene stage of the Tertiary series of formations, and therefore that the basalt eruptions took place in early Tertiary time. The volcanic episode to which these plateaux owe their origin was one of the most important in the geological history of Britain. It appears to have resembled in its main features those remarkable outpourings of basalt which in recent times have overspread some of the low grounds of Iceland, or those which in earlier periods deluged so many thousand square miles of the Western Territories of the United States. The eruptions were connected with innumerable fissures in which the basalt rose, and from numerous points on which it flowed out at the surface. These fissures, with the basalt that solidified in them, now form a vast assemblage of dykes, which cross Scotland, the north of England, and the north of Ireland, in a prevalent north-west and south-east direction. The dykes increase in number as they are followed westwards, and reach their chief development among the basalt-plateaux. They are not the only evidence of the prodigious energy with which molten material was forced upward into and through the terrestrial crust. Besides the dykes there occur around the plateaux vast numbers of small veins and threads of basalt which have been injected into the rocks. Some remarkable examples of these abundant intru-

[1] This tree was first noticed by MacCulloch (*Western Isles*, i. p. 258 and Pl. xxi. Fig. 1), and subsequently by Mr. Starkie Gardner (*Quart. Journ. Geol. Soc.* xliii. p. 283). The photograph for Fig. 38 was taken by Mr. J. R. Wharton, son of my friend Sir William Wharton, hydrographer of the Admiralty, who kindly supplied it after his visit to the locality under the precipices of Gribon last summer. An interesting feature of the section is the manner in which the jointing and curved columns of the basalt diverge from the side of the tree. The wood, except at the lower part, had decayed during the volcanic period, leaving a hollow cylinder into which detritus was washed from above, before the whole was buried under the overlying basalts.

sions are to be seen along the cliffs to the south of the Point of Ardnamurchan (Fig. 52).

That the volcanic period was a prolonged one is proved by the great denudation of the plateaux before the last eruptions took place. This is impressively exemplified in the Isle of Eigg, which will be more specially described in the following chapter. A remarkable feature in the volcanic phenomena was the subsequent disruption of the basaltic plateaux by large bosses of gabbro and of various granitoid rocks, and by the injection of innumerable sills of basalt and dolerite. The gabbro now towers into conspicuous groups of hills—the Cuillins, the mountains of Rum and Mull, and the rugged heights of Ardnamurchan. The granite rises into the cones of the Red Hills in the south of Skye. The sills appear everywhere as terraced and often columnar escarpments along the slopes and precipices of the basalt-plateaux.

Under the Post-tertiary division of geological time come the records of the Ice Age, when Scotland was buried under sheets of ice which ground down, striated, and polished the harder rocks over the whole country, and left behind them widespread accumulations of clay, gravel, and sand, known as glacial deposits or "drift." The nature of the evidence and the deductions drawn from it have been already stated in Chapter IV., but a full description of the glaciation of the Highlands will be given in Chapter XI. The youngest geological formations of the Highlands are the raised beaches, river-terraces, lake-deposits, peat-mosses, and other accumulations, which are related to the present configuration of the country, and contain remains of the plants and animals still living on its surface.

CHAPTER VII

THE TABLE-LAND OF THE HIGHLANDS

If the observer who has mastered the geological details given in the foregoing chapter would grasp at once the leading features of Highland scenery and their relation to geological structure, let him betake himself to some Highland mountain-top that stands a little apart from its neighbours, and looks over them into the wilds beyond. A better height could not be chosen than the summit of Ben Nevis. None other rises more majestically above the surrounding hills, or looks over a wider sweep of mountain and moor, glen and corry, lake and firth, far away to the islands that lie amid the western sea. In no other place is the general and varied character of the Highlands better illustrated. And from none can the geologist, whose eye is open to the changes wrought by sub-aërial waste on the surface of the country, gain a more vivid insight into their reality and magnitude. To this, as a typical and easily accessible locality, I shall have occasion to refer more than once. Let the reader, in the meantime, imagine himself on the highest peak of the British Isles, watching the shadows of an autumnal sky as they steal over the vast sea of mountains that lies spread out, as in a map, around him. And while no sound falls upon his ear, save now and then a fitful moaning of the wind among the snow rifts of the dark precipice below, let him try to analyse some of the chief elements of the landscape. It is easy to recognise the more marked heights and

hollows. To the south, away down Loch Linnhe, he can see the hills of Mull and the Paps of Jura closing in the horizon. Westward, Loch Eil seems to lie at his feet, winding up into the lonely mountains, yet filled twice a day with the tides of the salt sea. Far over the hills, beyond the head of the loch, he looks across Arisaig, and can see the cliffs of the Isle of Eigg and the dark peaks of Rum, with the Atlantic gleaming below them. If the air be clear, as it often is in that climate towards sunset, he may even behold the long broken line of the Outer Hebrides half sunk in the sea a hundred miles away. Farther to the north-west the blue range of the Cuillin Hills rises along the sky-line, and then, sweeping over all the intermediate ground, through Arisaig and Knoydart and the Clanranald country, he can mark mountain beyond mountain, ridge beyond ridge, cut through by dark glens, and varied here and there with the sheen of lake and tarn. Northward runs the mysterious straight line of the Great Glen, with its chain of lochs. Thence to east and south the same billowy sea of mountain-tops stretches out as far as eye can follow it—the hills and glens of Lochaber, the wide green strath of Spean, the grey corries of Glen Treig and Glen Nevis, the distant sweep of the moors and mountains of Brae Lyon and the Perthshire Highlands, the spires of Glen Coe, and thence round again to the blue waters of Loch Linnhe.

In musing over this wide panorama, the observer cannot fail to note that while there are everywhere local peculiarities in the outline of the hills and in the shapes of the sides of the valleys, there is yet a general uniformity of contour over the whole. What seem, at a nearer view, rough craggy peaks and pinnacles, seen from this height are dwarfed into mere minor irregularities of surface. And thus over the whole of the wide landscape, one mountain ridge appears after another, with the same large features, raising their smooth backs or their notched and craggy crests from glen to glen, but broken now and again where from some hidden valley a circular corry or naked cliff lifts itself bare to the sun.

Much has been said and written about the wild tumbled sea of the Highland hills. But, as he sits on his high perch, does it not strike the observer that there is after all a wonderful orderliness, and even monotony, in the waves of that wide sea? And when he has followed their undulations from north to south, all round the horizon, does it not seem to him that these mountain-tops and ridges tend somehow to rise up to a general level, that, in short, there is not only, on the great scale, a marked similarity of contour about them, but a still more definite uniformity of average height? (Figs. 27, 39). To many who have contented themselves with the bottom of the glen, and have looked with awe at the array of peaks and crags overhead, this statement will doubtless appear incredible. But let any one get fairly up to the summits and look along them, and he will not fail to see that the statement is nevertheless true. From the top of Ben Nevis this feature is impressively seen. Along the sky-line, the wide sweep of summits undulates up to a common level, varied here by a higher cone, and there by the hollow of some strath or glen, but yet wonderfully persistent round the whole panorama. If, as sometimes happens in these airy regions, a bank of cloud with a level under-surface should descend upon the mountains, it will be seen to touch

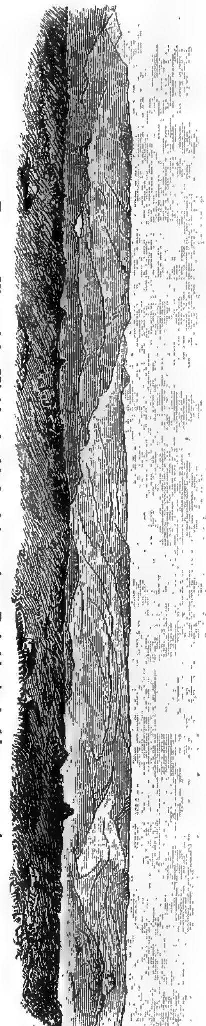

FIG. 39.—View of the Highland table-land from above Dalwhinnie, looking westward.

summit after summit, the long line of the cloud defining, like a great parallel-ruler, the long level line of the ridges below. I have seen this feature brought out with picturesque vividness over the mountains of Knoydart and Glen Garry. Wreaths of filmy mist had been hovering in the upper air during the forenoon. Towards evening, under the influence of a cool breeze from the north, they gathered together into one long band that stretched for several miles straight as the sky-line of the distant sea, touching merely the higher summits, and giving a horizon by which the general uniformity of level among the hills could be signally tested. Once or twice in a season one may be fortunate enough to get on the mountains above such a stratum of mist, which then seems to fill up the inequalities of the general platform of hill-tops, and to stretch out as a white phantom-sea, from which the highest eminences rise up as little islets into the clear air of the morning.

There are many easily accessible summits from which this long level line of the Highland hill-tops may be impressively observed. In the very centre of the Highlands, for instance, from the hills north-east of Dalwhinnie, which reach heights of over 2000 feet, an uninterrupted view may be had over the vast sea of mountains lying between Strathspey and the Great Glen, as well as up into the higher Grampians. Looking across Loch Laggan, one can take in the whole range of heights, some of them 3700 feet above the sea, from the head of Glen Spean round to the far corries at the sources of the Spey, the mountains that encircle the Pass of Corryarrick, and those that continue the range eastwards into the Monadhliath group. Yet no one who had not been actually among those high grounds could imagine them, as seen from above Dalwhinnie, to be so deeply trenched with glens as they are. From that centre they present one long scarcely broken line of upland (Fig. 39).

Not less striking is the example furnished by the central mass of the Grampians, comprising the Cairn Gorm Mountains

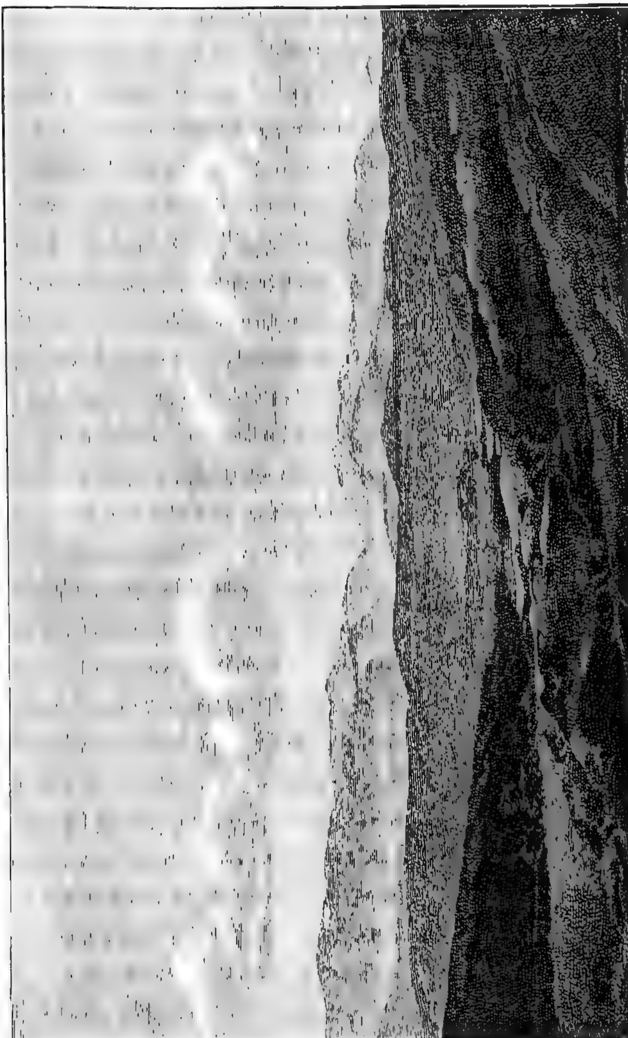

FIG. 40.—View of the highest group of the Grampians from the south. (From a photograph by Mr. George Barrow.) The glen in the centre of the range is that of the Dee; the mountain on the right is Ben Macdhui; the cliff on the left, the Devil's Point; and the mountain ridge above it, that of Cairn Toul and Braeriach.

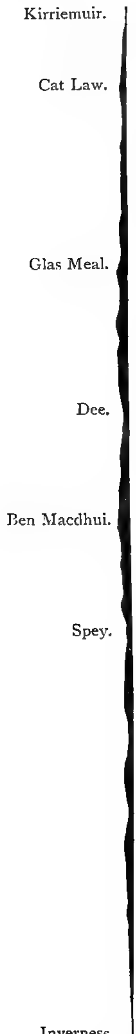

FIG. 41.—Section of the Grampian Range from Inverness to Kirriemuir. (Vertical and horizontal scale the same.)

and the great corries and precipices round the head of the Dee. This tract of rugged ground, when looked at from a distance, is found to present the character of a high undulating plateau. The accompanying figure (Fig. 40) shows how this feature appears as seen from the south about twelve miles away. But there are tracts of the Eastern Grampians, 3000 feet or more above sea-level, which, though including the tops of the mountains, extend for mile after mile as a wide undulating plateau. More detailed reference will be made to this region in Chapter IX.

The long level line of the Highland mountain-tops may be seen not only from some commanding eminence among the mountains themselves, but perhaps even more markedly from the lower country outside, as I have already remarked in the introductory outline of the physical features of the Highlands. From the Isles of Skye and Eigg, for instance, the panorama between the heights of Applecross and the Point of Ardnamurchan shows in a most impressive manner the traces of the old table-land. So, too, when the observer ascends the ridges behind the town of Greenock, the hill-tops of the opposite Highlands, between Innellan and the head of Loch Long, stretch out before him in a long and almost straight line (Fig. 27).

A section drawn across the Highlands, on the same scale for vertical as for horizontal distance, brings out clearly the comparative insignificance of the eminences which we dignify

with the name of mountains, and shows how gently a line drawn along the tops of the ridges descends on either side from the axis of the country (Fig. 41). From the top of Ben Macdhui (4296 feet), for example, north-westward to the crest of the hills overlooking the Moray Firth (say 1300 feet above the sea-level), is a distance of about twenty-eight miles, and the angle of descent would be not more than about 1 in 50. From the same central elevation to the south-eastern verge of the Highland mountains the angle would be not quite so much, as the distance is rather more, and the average height of the broad table-land there is greater than on the opposite border. These slopes would not be so steep as some railway gradients now in use.

What does this general uniformity of level mean? It has plainly nothing to do with geological structure. On the contrary, from the extraordinarily crumpled, plicated, and dislocated condition of the Highland rocks, we might have expected the external configuration of the country to have borne a close relation to that disturbed structure: to have risen into huge irregular mountains where the rocks had been thrust upwards, and to have sunk into deep hollows and clefts where they had been depressed and fractured. But the most cursory examination suffices to show that between the outer forms of the surface and the inner grouping of the rocks there is no such relationship. Everywhere we see the abraded edges of the strata of schist running along and across the hill-tops. The arches into which the rocks have been folded have been worn deeply down. The faults which have dislocated and depressed them have been so levelled off that their position can often only be determined by laborious search, though they have also served to guide the denuding agents in the excavation of many valleys. In short, no fact in Scottish geology can be more abundantly demonstrated than that a vast thickness of rock has been denuded from the general surface of the Highlands since the rocks were broken, plicated, and metamorphosed.

One of the most impressive proofs of this want of dependence of external configuration upon internal structure is furnished by the frequent troughs and arches, or *synclines* and *anticlines*, into which the schists have been folded. It might have been expected that the arches should form lines of elevated ridge, and the troughs lines of glen or strath. But where any relationship between the geological and topographical features exists, it is commonly just the reverse of this. The basins or troughs rise into rugged and lofty mountains, while the arches are occupied by deep valleys. A striking example of this feature is to be found in Ben Lawers (3984 feet). That wide-based, broad-shouldered mountain rises from the valley of Loch Tay on the one side, and sinks into Glen Lyon on the other. It forms thus

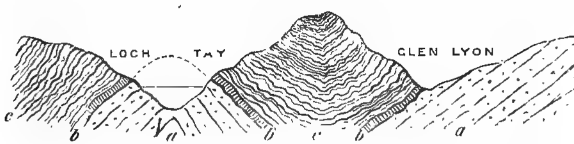

FIG. 42.—Generalised diagrammatic section of Ben Lawers, Perthshire. *a*, Quartzose rocks. *b*, Limestone. *c*, Schistose rocks.

a huge dome-shaped mass between two deep valleys. But instead of owing this form to an upward curving of the schists, it actually lies in a contorted basin of these rocks, which dip underneath the mountain on the banks of Loch Tay, and rise up again from its further skirts in Glen Lyon. Thus Ben Lawers is in reality formed of a contorted trough of schists, while the valley of Loch Tay runs along the top of an anticlinal arch. Hence that which, in geological structure, is a depression has by denudation become a great mountain, while what is an elevation has been turned into a deep valley.[1]

Examples of this structure, teaching the same lesson of vast

[1] The representation of the structure of Ben Lawers given in Fig. 42 is generalised for the sake of simplicity. The trough really consists of a succession of minor corrugated basins. See Section 2 on the Geological Map of Scotland (Plate III.), accompanying this volume.

degradation, may be met with all over the Highlands. Not less striking is the evidence that some of the most powerful dislocations in the region have been planed away till they do not now seriously influence the topography. Nowhere can this be better seen than in the north-west of Sutherland. As I have already stated, that district contains some of the most astonishing proofs of subterranean displacements. In the Section No. 1 on the Geological Map accompanying this volume, the Lewisian gneiss is shown to have been driven westwards across the Cambrian strata, the thrust-planes between them undulating at low angles. By a subsequent series of movements, these gently inclined dislocations have been cut through by ordinary or normal faults, some portions of the fractured ground being thrown down for several hundred feet. It will be seen, however, that so vast has been the denudation, that the greater part of the overlying rocks has been removed, that neither the faults nor the thrust-planes produce lines of cliff or ravine at the surface, but, on the contrary, are without effect on the contour of the ground, except in so far as they may have brought hard and soft rocks side by side.

Other impressive examples of the comparatively insignificant effect of the most gigantic dislocations upon topographical features might be cited from many widely separate parts of the Highlands. Let me only refer to one remarkable group which affords an instructive lesson in showing that while faults have undoubtedly given a trend to some valleys and glens, it has not been by their immediate effects on the surface, but by their subsequent influence in guiding the processes of denudation.

The group of faults in question has been detected in the course of the Geological Survey of the Central Highlands. These dislocations, traversing obliquely the general strike of the formations, run in a general north-north-easterly direction, but tend to turn towards the north, or even west of north, in their northward extension. The most easterly of them

starts from the very edge of the southern Highlands, at Aberfoyle, whence it bends away from the great border-fault, crosses Loch Vennachar near its upper end, and strikes over the eastern slopes of Ben Ledi, across Loch Lubnaig northwards by Glen Ample to Loch Earn, which it crosses a little below Lochearnhead. It then pursues its course over the hills to Loch Tay, to which it gives the north-north-east trend of that part of the lake between Ardeonaig and Fearnan. Striking still in the same direction, it crosses the foot of Glen Lyon, traverses the valley of the Tummel below Tummel Bridge and Glen Garry above Blair Athol, keeps to the west of Glen Tilt, and, sweeping through the central Grampians, makes for Glen Feshie on the west side of the Cairngorm granite, and so into Strathspey—a total length of more than seventy miles.

A second fault has been followed from the Braes of Balquhidder over the ridge and across Glen Dochart and Glen Lochay to Glen Lyon at the Bridge of Balgie. It then holds on in the same course across Loch Rannoch northward into the line of Loch Garry.

A third line of fracture, probably one of the most important in the Highlands, has been traced from Glen Fyne through mountain and glen by Tyndrum and Loch Lyon to the upper end of Loch Rannoch, whence it seems to bend round northward so as to enter and follow the long hollow of Loch Ericht. But, looking at the course of this dislocation, we may plausibly infer that it continues seaward far beyond its landward limit in Glen Fyne, that it follows the line of Loch Fyne and may even have given the initial direction to that fjord, and that it continues by the two Lochs Tarbert across Cantyre into the western sea.

A fourth line of rupture has probably determined the trend of the long hollow of Loch Awe, for it has been traced in a wonderfully straight line from the eastern flanks of Ben Cruachan, following the same trend as Loch Awe, through the hills to Inveroran, thence across the Moor of Rannoch and along the

hollow of Loch Lydoch to the upper end of Loch Ericht, whence, coalescing with the fault last mentioned, it appears to hold along that line of depression, and thence by Glen Truim into Strathspey.

It will be seen that in each of these examples the fault crosses many wide and deep valleys without altering their courses, while it also coincides with some lines of glen and lake. The independence of or coincidence with surface topography is thus obviously due, not to the original effect of the fractures, but to the influence which they have exerted in guiding denudation by providing lines of weakness and by bringing together rocks possessing different degrees of durability.

From every hill and valley throughout the whole length and breadth of the Highlands there comes the same unwavering and uncompromising testimony that the present surface is not that of the primeval uplift, but has been produced by prolonged and stupendous denudation. The table-land of the Highlands has been the work, not of subterranean action, but of superficial waste. The long flat surfaces of the Highland ridges, cut across the edges of the vertical strata, mark, I believe, fragments of a former base-level of erosion. In other words, they represent the general level to which the Highland region was reduced after protracted exposure to sub-aërial and probably to marine denudation. The valleys which now intersect the table-land, as we shall immediately see, have been eroded out of it. If, therefore, it were possible to replace the rock which has been removed in the excavation of these hollows, the Highlands would be turned into a wide undulating table-land, sloping up here and there into long central heights, and stretching out between them league after league with a marked uniformity of level.

The first fact, then, which a study of the topographical features and geological structure of the Highlands establishes, is that the ancient land, formed after the stupendous movements that gave the rocks of the region their present characters,

was worn down by prolonged denudation. What the original topography of this land may have been we have no means of even conjecturing. Possibly the convulsions of which the rocks retain the records may have upheaved the region into ranges of lofty mountains stretching for hundreds of miles along the north-west of Europe, from beyond the west of Ireland to the farthest headlands of Scandinavia. But that topography, whatsoever it may have been, disappeared long ages ago. Its mountains were levelled down, until finally the region may have been reduced to a base-level of erosion beneath the waves. We do not require to suppose that the whole of the area was simultaneously submerged, or that the long ages of denudation may not have been varied by upheavals and depressions time after time. Some central tracts of higher ground may have been ultimately left as islands, which may possibly be represented by such ridges and peaks as those that rise above the table-land of the eastern Grampians, while by a succession of subterranean movements the progress of erosion may have been seriously modified.

The next question for determination is to fix, as far as may be possible, the geological date of this denudation. From the evidence alluded to in the foregoing chapter, we can affirm with confidence that an enormous amount of destruction of the surface must have been accomplished between the time of the Cambrian and Lower Silurian rocks and that of the Lower Old Red Sandstone. Not improbably the waste began, in the Silurian period, after the plication and metamorphism of the schists, and continued during a long series of ages into the period of the Old Red Sandstone. An examination of the fringe of conglomerate and sandstone round the Highlands shows conclusively that not only were the schists as metamorphosed and plicated as they are now before the time of the Old Red Sandstone, but also that they had undergone stupendous denudation. This conclusion bears so directly upon the history of the present scenery of the region that the

evidence on which it is based may with advantage be laid before the reader.

From the geological map, the general position of the Old Red Sandstone fringe and its outliers within the Highland area may readily be understood. But the map does not convey any adequate impression of the very marked unconformability to be seen on the ground, nor of the clear proofs that the younger formation once stretched far and wide over the crystalline schists, whence it has been since stripped off. At the southern edge of Caithness, for example, the conical mountain of Morven rises to a height of 2313 feet, as a conspicuous landmark all over the north of Scotland. Tower-

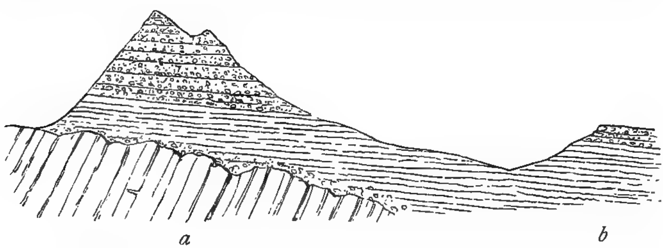

FIG. 43.—Section of Morven, Caithness. *a*, Crystalline schists. *b*, Old Red Conglomerate and Sandstone.

ing far above the platform of the crystalline schists in Sutherland, and also above the flagstone plain of Caithness, it looms up on the southern horizon as seen from the Orkney Islands. Rising almost from the edge of the sea, it stands out as the last great headland on the northern sky-line when viewed from the southern shores of the Moray Firth. This commanding position acquires much significance from the internal structure of the mountain. Morven and the adjacent cone of the Maiden Pap are a prolongation of the base of the Caithness Old Red Sandstone. They consist of nearly horizontal strata, and stand as vast pyramids upon the low region of schists which they so proudly overlook. The section in Fig. 43 shows that the schists must have been worn down into a platform

before the conglomerates formed out of their ruins were piled upon them. It likewise indicates how greatly the Old Red Sandstone itself has afterwards suffered from denudation, for the gently sloping strata undoubtedly at one time stretched far to the westward.

Similar evidence is yielded by the chain of rounded, craggy, conical hills between Golspie and Helmsdale, mounting sometimes to nearly 2000 feet above the sea, and presenting the abraded ends of the strata towards the interior. It is impossible to look at these brown hills without being convinced that they remain as a mere fragment of a great sheet of conglomerate and sandstone which stretched away westward across the abraded platform of schists, forming the interior of Sutherland. But as if to make this point quite certain, in the very heart of the county, the two solitary conical mountains of Ben Griam, 1936 feet, which rise so conspicuously above the worn platform of old crystalline rocks, are cakes of conglomerate formed out of the detritus of the schists on which they lie (Fig. 44). So, again, along the northern shores, outliers of the same kind, but on a smaller scale, are found from the borders of Caithness to Roan Island, sometimes in little patches standing high among the inland hills. Much farther to the south other outliers have been detected on the ridges to the west of the ridge of Ben Wyvis. Hence it must be inferred that a large part, if not the whole, of the counties of Sutherland, Ross, and Cromarty was once covered with a sheet of Old Red conglomerate, of which there are now left only a few relics capping some of the heights of the interior and fringing the coast-line. The same deposit runs southward from Caithness along the western shores of the Moray Firth, and stretches up the valley of the Great Glen[1] where it rises in Mealfourvonie (Meall Fuar-mhonadh, rounded hill of the cold moor) to a height of 2284 feet. Thence it sweeps eastwards along the seaboard of the counties of Inverness, Nairn, Elgin, Banff (Fig. 45),

[1] This valley, therefore, must be as old as the Lower Old Red Sandstone.

and Aberdeen, and detached portions are found thirty or forty miles off in the interior. Some of these outliers are bounded on one or more sides by faults, and probably owe their preservation to this circumstance, as will be referred to farther on in connection with the denudation of the Old Red Sandstone. The highest of them is that which runs up the valley above Tomintoul, where it reaches a height of upwards of 1300 feet above the sea. The coarseness of the conglomerate at this locality is remarkable. Huge blocks of the schists and

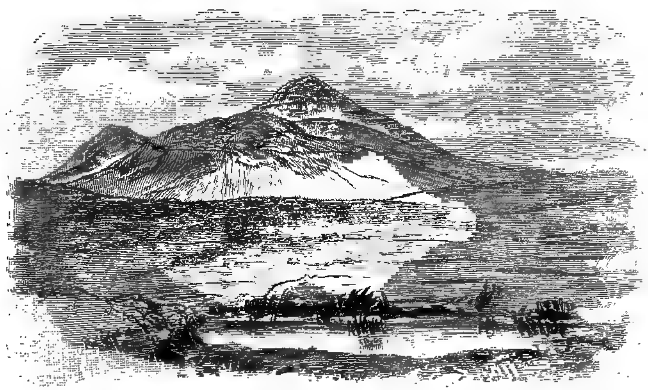

FIG. 44.—View of Ben Griam, Sutherland. The lower part of the hill consists of the Highland schists, the upper part of nearly level beds of Old Red Conglomerate and Sandstone.

other crystalline rocks of the district, piled up in the conglomerate there, bear emphatic witness to the abrasion of the Highlands during, as well as before, the time of the Old Red Sandstone. Whether, therefore, we look on these outliers as marking the sites of inlets from a great lake, which at that ancient period lay to the north, or of little independent lake-basins, they show that the platform of the Highlands had been extensively eroded before the conglomerates of the Old Red Sandstone were deposited.

Along the southern border of the Highlands, the evidence

is less obtrusive, but not less definite. From sea to sea, the Highland mountains are there flanked with the Old Red Sandstone, in low rolling plains that creep up to the base of the hills, but sometimes, as in the Braes of Doune, mount into long heathery heights, that form a kind of outer rampart to the main mass of the Highlands. Even from a distance the stratification of the conglomerates and sandstones of these uplands can be easily traced, the beds presenting their denuded, truncated ends towards the mountains, to which they evidently at one time reached, and from the waste of which they were formed (Fig. 46). If we prolong with the eye the lines of these truncated strata, we see that they probably once stretched far away into the interior of the Highlands.

But a closer examination of the ground brings out into still clearer light the relation of the conglomerates to the schists. I have already spoken of the great fault which runs across the island from sea to sea along the southern margin of the Highlands. The strata on the south side of this dislocation have been placed on end, sometimes for a couple of miles back from the line of fracture. Whether we suppose them to have been thrown down, or those on the opposite side to have been pushed up, the amount of vertical displacement must amount to many hundred feet (Fig. 47). If, therefore, we try in imagination to undo the effect of the fault and replace the rocks in their original relative positions, we see that the Old Red Sandstone must have extended far over the Highlands on their southern as well as on their northern side, resting everywhere upon a worn platform of schistose and eruptive rocks.

By thus piecing together the evidence furnished by the Old Red Sandstone along the borders and in the interior of the country, we obtain a strong probability that the great denudation which levelled the old Highland table-land was far advanced before the close of the Old Red Sandstone period. The vast piles of conglomerate and sandstone forming the Old Red

Sandstone system, and attaining a depth of 15,000 or 20,000 feet, represent a portion of the material worn away from the surface of the table-land. What the condition of the region was at the end of the Old Red Sandstone period can only be dimly conjectured. There appears, indeed, to be good reason to believe that, during the continuance of that

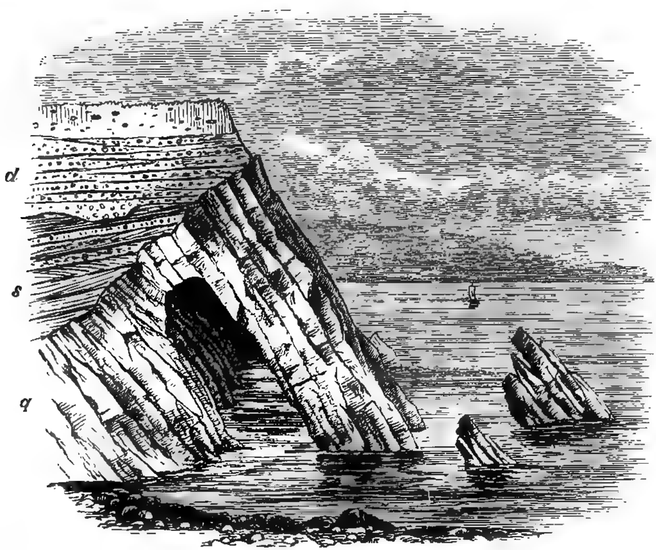

FIG. 45.—Unconformability of Old Red Sandstone (*s*) upon the Highland quartzite (*q*), with overlying glacial clays and gravels (*d*). Cullen, Banffshire.

period, there was a prolonged subsidence of the basins of the large lakes. The sinking of the floors of these hollows might not improbably be accompanied by an upheaval of the surrounding land, which in some measure compensated for the prolonged and enormous denudation. There can be no doubt that by the close of the Lower Old Red Sandstone period much of at least the Highland border was buried under conglomerates and sandstones. No means now exist of ascertain-

ing how much of the area, if indeed any portion of it, remained exposed. A great gap in the evidence here occurs. We know that the lakes of the Lower Old Red Sandstone had been partly or wholly effaced before the time of the Upper division of the same series of formations. But the general condition of the Highland region can only be guessed at. Whether it was land or whether it remained at a base-level of erosion below the sea is quite uncertain. There are indications of the proximity of land in the Western Highlands during Carboniferous time, and in the Northern and North-western Highlands in early Secondary time. The Jurassic sea undoubtedly extended far across these regions. The sea in which the Chalk was laid down must have spread over at least the lower part of the country, for the land in the western parts of Argyllshire, to judge from the height at which the Chalk now occurs there, must have been not less than 1500 feet lower in level than at present. But in early Tertiary time that region had once more become dry land, as is proved by the plant-remains preserved between the successive sheets of basalt in the Inner Hebrides.

In tracing back the history of the planing down of the general surface of the Highlands, we derive much light from an examination of the great Tertiary basaltic plateaux of the west.[1] I have spoken of these as probably fragments of a once continuous plain of lava that stretched for many miles along the great valley, now chiefly covered by the Atlantic, between the Western Highlands and the chain of the Outer Hebrides. It becomes of importance, therefore, to determine how much they have suffered from denudation, for we thereby obtain some measure of the amount of erosion which the general area of the Highlands may have undergone since the early Tertiary periods.

Now, it is no exaggeration to say that of the vast lava

[1] For full details of this subject, the reader is referred to my *Ancient Volcanoes of Britain*, vol. ii. (1897).

FIG. 46.—Craig Beinn-nan-Eun (2067 feet) east of Uam Var (Uamh Mhòr, Big Cave). Old Red Conglomerate, with the truncated ends of the strata looking into the Highlands, moraines of Corry Beach in foreground.

streams which, to a depth of more than 3000 feet, were poured out in the west of Scotland, only a group of scattered fragments remains. In Ben More, Mull, the loftiest of these fragments, we can walk over each bed of basalt from the sea-level to the mountain top, a height of 3169 feet (Fig. 48). These nearly level sheets of once molten rock present their truncated ends on all sides, and must obviously have extended far beyond the mere isolated cone to which they have been reduced. The two tabular hills, known as Macleod's Tables, which form such conspicuous landmarks in the north-west of Skye, rise to a height of 1600 feet, and are in like manner built up of horizontal lava beds which once spread away out

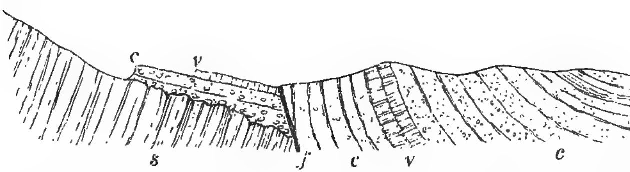

FIG. 47.—Section across the boundary fault of the Highlands at Glen Turrit, Perthshire. *s*, Crystalline schists of the Highlands. *cc*, Conglomerate and sandstone (Old Red Sandstone), with *vv*, associated volcanic rocks. *f*, Fault.

into the Atlantic on one side, and over the hills of Skye on the other (Fig. 49). In Morven a little outlier of basalt caps the gneiss hill of Ben Iadain, and reaches a height of 1873 feet (Fig. 50). It looks far across Argyllshire, and that the basalt once stretched eastward across what is now a region of mountain and glen is indicated not merely by its position, but by the fact that its basalt probably belongs to the lower part of the volcanic series, for it is immediately underlain by the thin band of Cretaceous rocks that form part of the floor on which the lavas were poured out. A large fault, with a throw of probably about 1500 feet, separates it from the continuation of the same rocks in the great escarpment of Morven.

But not only do the detached outliers bear witness to the enormous erosion of the level sheets of basalt. Their evidence

is supplemented and enforced by that of the numerous glens and lochs which have been excavated in the plateaux. No one, for instance, can sail through the Sound of Mull and note the level bars of rock on either side without being convinced that these were once prolonged across the strait between Mull and the mainland; but since that time the Sound has been cut through them some twenty miles long, a mile and a half to nearly three miles broad, and from crest to crest of the opposite hills at least 2000 feet deep. Still more striking, perhaps, is Loch Scriden, which deeply indents the western side of Mull. On either side the horizontal basalts rise terrace above terrace, till, in the bold headland of Gribon, they reach a height of more than 1600 feet above sea-level. The distance across from crest to crest of the ridges is rather more than four miles, and the depth from a line joining the crests down to the bottom of the loch is about 1800 feet. The relative proportions of the removed material may be seen in Fig. 51, which, however, probably represents only a small part of the denudation. Gribon runs eastward into Ben More, and looking across at its terraced slopes we can easily see that it must have been covered with at least the lavas left in that mountain—that is, with 1500 feet of additional rock (see Fig. 48).

In Rum and in Skye similar evidence presents itself in abundance. But to a trained geological eye it is there still more impressive, inasmuch as the higher mountains consist of eruptive material which certainly did not reach the surface, but consolidated under a pile of volcanic materials which have since been entirely stripped away. All over the Western Highlands it is manifest that the Tertiary volcanic rocks have been trenched to the very core, hundreds of feet of lava have been worn away from their surface, and long deep glens, quite comparable with those in the more ancient schists of the Highlands, have been dug out of them.

There is yet another kind of evidence which appeals not less forcibly to the imagination as a testimony to the vast

degradation of the country since older Tertiary time. I have referred to the innumerable intrusive veins (Fig. 52) found beyond the area of the basalt-plateaux and to the parallel dykes which, with a general north-west and south-east direction, can be traced up to the plateaux. Most of these dykes are almost certainly not older than early Tertiary time. Now it is obvious that wherever the lava rose in the fissures to the surface it might flow out in a stream, and must have done so if the contour of

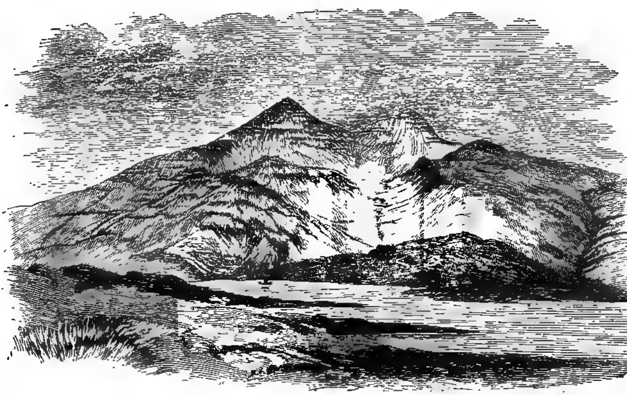

FIG. 48.—View of Ben More, Mull, composed of nearly horizontal sheets of lava, from the south side of Loch Scriden.

the ground had been at all like what it is now. The dykes run over the tops of hills 3000 feet high, descend from these elevations into deep valleys, and cross lakes whose bottoms are actually below the sea-level. Remarkable examples occur in the district of Loch Lomond. One of the dykes, 20 to 30 feet broad, traverses Ben Vorlich at a height of 2950 feet, and sweeps down the mountain side to Loch Lomond, which it crosses. Reappearing on the other side of the lake, it ranges across ground more than 2000 feet in elevation, and then plunges into Loch Katrine. The difference of level between the dyke near the top of Ben Vorlich and the bottom

of Loch Lomond is 3130 feet.[1] Had the deep trough of Loch Lomond been in existence when this fissure was filled with lava, the molten rock never could have risen to the summits of the hills on either side, but would have poured out upon the lake-floor and filled up the hollow. Here, then, is a demonstration that, since older Tertiary time, a mass of schists more than 3000 feet thick has been removed by denudation, and a deep wide glen has been eroded. But it is only the happy accident of the dyke occurring there that has enabled us to reach this demonstration. If, however, such a result has

FIG. 49.—Macleod's Tables, Skye.

been achieved in one part of the Highlands, it shows how prodigious the denudation must have been over the whole region since older Tertiary time.

Of the successive stages of this vast erosion we know nothing, for the memorials of them have been swept away, and we see now only the ultimate result. But that the waste began and had made some progress before the close of the volcanic eruptions of the Inner Hebrides is admirably revealed in some of the islands.[2]

The Scuir of Eigg, off the west of Argyllshire, stands out as one of the most striking monuments of denudation in the British Islands (Frontispiece and Fig. 53). No feature of the western

[1] These measurements were made for me by Mr. H. M. Cadell, who mapped the ground in the course of the Geological Survey.

[2] See *Ancient Volcanoes of Britain*, vol. ii. chaps. xxxviii. and l.

coast takes the traveller so much by surprise as the singular ridge which runs along the hill-tops at the south end of the Island of Eigg, and forms the well-known Scuir. Seen from the sea on the east side, this ridge rises as a lofty massive column, towering to the height of some 400 feet above the high ground on which it stands, and 1289 feet above the sea. Its eastern front is quite vertical, so much so, that if one has a steady enough head to stoop over the edge of the precipice he may see its base 400 feet below. What seems a broad and lofty tower, when looked at from the east, is really the abrupt end of a long narrow ridge, which widens out westward until it loses itself in a mass of rugged ground, abounding in little rock-basins filled with water. The Scuir itself, with these broken heights into which it merges, consists of a black glassy rock known as "pitchstone," almost everywhere columnar, the columns being sometimes piled up horizontally with their weathered ends exposed, sometimes slanting inwards or outwards, like a *chevaux de frise*, and often built round a hummock of rock, very much in the way the peasants stack their peats. It is a thoroughly volcanic rock, having been poured forth in successive streams of molten lava, and having assumed columnar forms as it cooled and consolidated.

At either end of the long ridge, this pitchstone is seen to lie upon a hollow eroded out of the underlying level sheets of basalt and filled up with compacted shingle. Among the rounded stones of this shingle-bed there is an abundance of coniferous wood, in chips and broken branches, yet so well preserved that, when newly taken out and still damp, it might be taken, but for its weight, for the relics of some old pine-forest buried in a peat-bog.

The hollow in which the shingle lies is evidently the channel of an ancient stream, which had eroded the older plateau-basalts. At the time when this stream was flowing, the Island of Eigg must have been joined to some higher land, possibly to the north or north-east, for the stream brought

down with it blocks of hard Torridon sandstone—a rock not found in Eigg, but abundant in Skye and Western Ross-shire, and also on the neighbouring Island of Rum. Where now is the ridge of the Scuir there was therefore a valley, watered by a stream that flowed with considerable volume to be able to carry along the blocks, sometimes two or three feet in diameter, which are found in its shingle. So long an interval had passed away since the eruption of the basalts, and these rocks had been so much abraded by atmospheric waste and

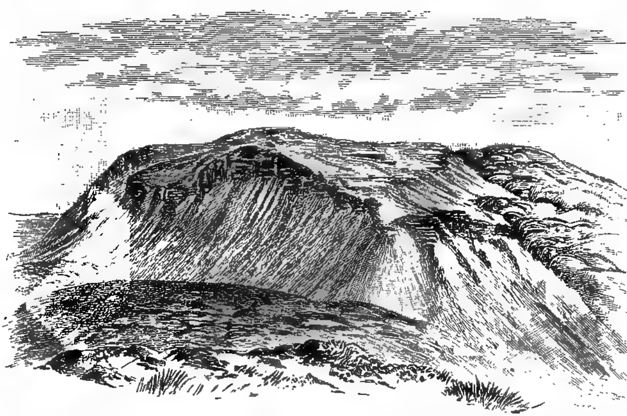

FIG. 50.—Ben Iadain, Morven. The hummocky ground below and on the right hand is formed of the Highland schists; the flat parallel sheets of basalt, overlying Secondary strata, cap the hill, and are shown to be brought down against the schists by two parallel faults (on the right hand).

running water, that a system of valleys had been carved out on the surface of the wide lava-field. But the volcanic eruptions had not finally died out in the west of Scotland. Eventually eruptions of black glassy pitchstone took place. Streams of this molten rock rolled along the main river-channel, and ascended for a short way the courses of some tributary streams, burying the whole under a mass of solid rock (Fig. 53).

As the buried river-channel of the Scuir slopes gently from east to west, it may be surmised that probably the river here

flowed westwards. That its course ran a good deal further seawards than the present limits of Eigg may be inferred from the abrupt truncation of the channel at the top of the cliff on the west side of the island. Confirmation of this inference is to be found on Hysgeir, a low islet about eighteen miles west from Eigg, consisting of columnar pitchstone precisely similar to that of the Scuir. It appears to be extremely probable that the ancient river which provided a channel for the descent of this lava pursued its course westwards for at least eighteen miles, and that it passed across the site of Hysgeir.

Further interesting traces of the same or some neighbouring stream which flowed from the Western Highlands across the lava-field are to be found in the Islands of Sanday and Canna, where relics may be seen of a river-ravine filled with

FIG. 51.—Section across Loch Scriden, Mull.

ancient fluviatile gravel and silt. The extensive sheets of gravel intercalated there among the basalt-lavas consist chiefly of water-worn volcanic detritus, and prove how much the lava-plain was wasted even before the close of the volcanic period.[1]

But volcanic activity, though it greatly altered the topography of the Western Highlands, was only a temporary phase of geological evolution. It filled up river-valleys and otherwise changed the face of the land, but it did not arrest the progress of denudation. The processes of atmospheric disintegration at once began upon the cooled and solidified lava, and have been continued ever since. The result of the prolonged waste may be briefly summed up. The basalt-plateaux, which no doubt at one time not only spread in continuous lava-fields up to the base of the Western Highlands, but even rose high

[1] This interesting geological history will be found described in the chapters of *Ancient Volcanoes of Britain* cited *ante*, p. 167.

along the flanks of the mountains, and possibly stretched some way into the interior, have been so deeply trenched as to be reduced to a scattered group of islands. During this process of decay the topography of the remaining land has been profoundly changed. Thus in the Island of Eigg, the basalts forming the higher grounds that bounded the old river-valley have been worn down and reduced to slopes that shelve into

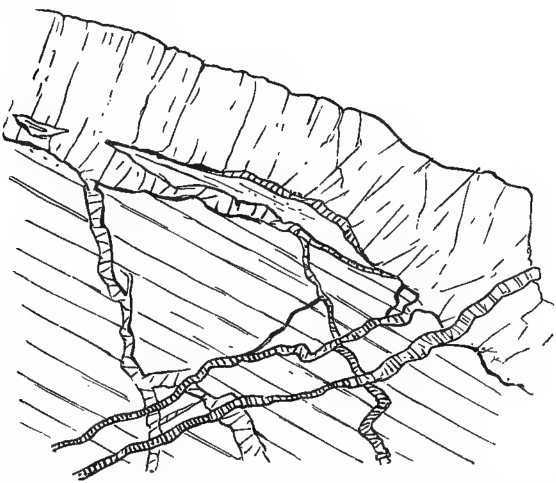

FIG. 52.—Veins of basalt traversing Jurassic strata, Ardnamurchan, Argyllshire.

the sea.[1] So complete has been the change that the buried valley, under protection of the singularly indestructible pitch-

1. The general aspect of the Scuir of Eigg is well shown in the frontispiece to this volume, which is taken from an excellent photograph by Mr. A. S. Reid. It will be seen in this figure that the gently-inclined sheets of basalt form all the lower ground, that they rise up the hill-slope till they reach the base of the eastern precipice of the Scuir, and that their truncated ends abut against the lowest sheet of the Scuir. Between them and the pitchstone the old river-gravel and drift-wood are found (see Fig. 53). The abrupt termination of the basalts against the pitchstone marks approximately the side of the old river-valley. The figure further shows clearly the alternation of glassy and devitrified sheets of pitchstone, marking the successive flows of lava by which the valley was filled up.

stone, now runs along the top of a ridge. What were once hills have disappeared, and what used to be a valley is now the crest of a lofty hill. The pitchstone, which, when it rolled down that ancient water-course, sought the lowest level it could find, rises to-day into one of the most conspicuous land-marks in the west of Scotland. Yet even of this firm rock only a fragment now remains, which is mouldering into ruins, and the debris of which is strewn thickly along the base of the cliffs. Every century must certainly, though perhaps to human eye imperceptibly, lessen the size of the Scuir, and we can look to a distant time when the last remains of it shall have disappeared. The lowering of the basalt-ground, no longer protected by the more durable pitchstone, will then proceed apace.

From all the evidence which has now been adduced it will, I think, be manifest to the reader that a comparison of the external configuration of the Highlands with their geological structure inevitably leads us to the conclusion that of the original surface of this part of the globe, as it was left after the crumpling and dislocation of the schists, not a vestige can possibly now remain; that thousands of feet of solid rock have since then been worn away from it; and that the present inequalities of the ground, instead of being memorials of primeval convulsions, are monuments of prolonged denudation. But while these deductions compel our assent, they by no means exclude all influence of subterranean movement upon external features. It will be my aim in subsequent chapters to bring forward abundant proof of that influence, and to show how it can be traced even where the proofs of stupendous denudation are clearest. The positions into which the rocks were thrown by contortions and dislocations have, in many cases, materially guided the powers of waste in the long process of superficial degradation. Larger features, such as hill ranges and lines of valley, have had their general trend determined by that of the anticlinal and synclinal foldings of the strata. Minor details,

which give individuality to the forms of cliff, crag, and mountain, have been largely dependent upon the several structures superinduced by underground movements upon rocks. But alike in the greater and the lesser elements of the scenery, there has been a presiding power of erosion, which, though its working has been modified by local circumstances, has laid its finger on every rood of the surface, and has carved out for itself the present system of glen and mountain, valley and hill.

The levelling down of the ancient table-land of the High-

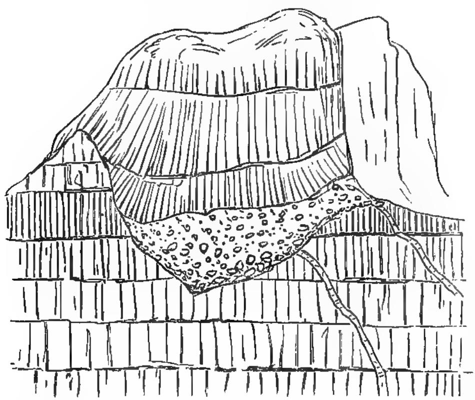

FIG. 53.—Section of west end of Scuir of Eigg, showing the basalt sheets traversed by dykes and covered with an old river gravel which is buried under pitchstone.

lands is shown to be of high geological antiquity. The process was begun before the Lower Old Red Sandstone, and has been continued with many interruptions from that time until to-day. That the table-land should now be traceable only in fragments, that it is cut down by wide straths and deep glens, and that its general surface has been most unequally eroded, need not be matter for surprise. When we reflect on its extreme age and on the long cycle of geological revolutions that have befallen it, the wonder rather is that any trace of it should now remain.

CHAPTER VIII

THE HIGHLAND VALLEYS

THOUGH an eminently hilly country, Scotland is not dominated by any leading mountain-chain, on which all the other topographical features are dependent. Even in the Highlands, where the highest elevations are reached, ridge succeeds ridge in endless succession, not one of them ever attaining such an altitude as to mark it out as a great central axis of upheaval. Nor is there any more evidence of a dominant line of elevation among the Southern Uplands. Seen, indeed, either from a distance or from any commanding summit in their midst, the high grounds of Scotland, as I have already remarked, seem to undulate up to a common average level, and are to be considered rather as a broken and sorely wasted table-land than as a series of true mountains. Careful examination soon shows that the dominant features are not the monotonous ridges, but the valleys that have been opened through them. If these valleys were filled up again with the material that has been eroded out of them, the high grounds, as we have now seen, would once more become what they probably were at first, elevated plains or plateaux, with no strongly-marked features, —no eminences rising much above nor hollows sinking much below the general surface.

Hence an inquiry into the origin of Highland scenery ought to trace the history of the valleys before that of the hills. At the outset, it should be remarked that among the

valleys of the Highlands, as in the rest of Scotland, certain prevalent types of form have been recognised in the popular names bestowed upon them. "Straths" are broad expanses of low ground between bounding hills, usually traversed by one main stream and its tributaries, such as Strath Tay, Strath Spey, Strath Conon. The name, however, has also been applied to wide tracts of lowland which embrace portions of several valleys, but are defined by lines of heights on either side. The best example of this use of the word is afforded by Strathmore—the "great strath"—between the southern margin of the Highlands and the line of the Ochil and Sidlaw Hills. This long and wide depression, though it looks like one great valley, strictly speaking includes portions of the valleys of the Tay, Isla, North Esk, and South Esk, all of which cross it. Elsewhere in Central Scotland such a wide depression is known as a "howe," as in the Howe of Fife between the Ochil and Lomond Hills. "Glen," the usual Gaelic epithet for the ordinary type of Highland valley, is applied to a narrower and steeper-sided valley than a strath, though the names have not always been applied with discrimination. The hills rise rapidly on either side of a typical glen, sometimes in grassy slopes, sometimes in rocky bosses and precipitous cliffs, while the bottom is cumbered with mounds of debris and scattered boulders, or is levelled out into a flat platform of alluvium through which a stream meanders. Occasionally the bottom of the valley is occupied by a lake. Where a glen contracts and its river flows through a rocky gorge, there is very commonly either a lake, or a meadow marking the former site of a lake, above the gorge. In Glen Falloch, for instance, some four or five such contractions with alluvial flats above them lie between Loch Lomond and the watershed.

Where two valleys head towards each other upon a mountain-ridge, and are connected by a marked depression in the line of watershed, the hollow, col, or pass between them is known in the Highlands as a "Balloch." Every gradation may be met

with, from a mere notch in a high ridge down to a nearly level continuous valley where, except by noting the flow of the drainage, it is hardly possible with the unaided eye to mark the position of the watershed.

A crescent-shaped hollow or half-cauldron on the side of a mountain is called in the Highlands a "corry" (Fig. 54), in Wales a "cwm." Not infrequently corries encircle the head-waters of rivers that take their rise among the loftier high grounds. Their sides are formed by steep rugged walls of rock, from the base of which long lines of debris, called "screes," descend to the bottom of the valley. The probable origin of ballochs and corries will be discussed farther on.

That valleys are essentially due to erosion has already been sufficiently enforced. It has likewise been pointed out that the original form of the terrestrial surface on which the process of erosion first began can only be conjectured. The plications of the earth's crust which folded the rocks of the Highlands and Southern Uplands not improbably upraised above the sea a series of longitudinal ridges having a general north-easterly direction. But such ridges, as was noted in the last chapter, were no doubt levelled down by the long-continued denudation which produced the Highland table-land. It was out of this subsequently upraised table-land that the system of valleys was carved. The prevalent north-east and south-west strike of the rocks would probably so far influence the denudation as to cause the resultant inequalities of surface to arrange themselves in lines of height and hollow in the same general direction. The earliest rain that fell upon the re-elevated surface would run off the ridges, first in transverse water-courses down each short slope, and then in longitudinal depressions wherever such had been formed. Once chosen, the pathways of the streams would be gradually deepened and widened. They would, as it were, sink into the framework of the land, and, no matter how much the general surface might be degraded, they would maintain their place so long as the land remained above water.

Nothing short of some stupendous revolution, that should break up or bury the surface of the land, would be able to efface them. But of such an event there is no trace. On the contrary, all the evidence goes to show that the valleys are due to prolonged erosion. They must consequently be regarded as among the most ancient topographical features in the country. Strange and almost paradoxical as the statement may seem, it is nevertheless true that they are of higher antiquity than the mountains that rise from them. The mountains, in fact, have emerged out of the original bulk of the land, in proportion as the valleys have been excavated. Their position has been determined by the lines of valley, and their forms have been shaped by the process of degradation.

We must conceive the denudation to have been continuously in progress, so long as the ground stood above the level of the sea; that, in short, it would only cease when it had reached its lowest possible limit, and had reduced the land to a submarine plain. We know that in the long history of the Highland region there were intervals of depression, when the ground lay partly or wholly below sea-level, and when, in some cases, it was buried under thousands of feet of accumulated sedimentary material. These masses of sediment would, of course, completely fill up the drainage-lines of the submerged land, and when the region reappeared above water, a new and independent series of lines would at once begin to be eroded upon its surface. The excavations of one period have thus been filled up by the deposits of another. We must also remember that, from time to time, subterranean movements would variously affect the flow of water and the lines engraven by it over the surface of the land.

It will be obvious that when a land-surface which, with its characteristic topography, has been submerged and buried under thick sheets of sediment, is once more raised into the air, the subsequent degradation of these overlying sediments may reveal portions of the older topography. Ancient valleys

obstructed by detritus may be partially uncovered, and may even serve again as channels for the drainage. Now this is actually the case in Scotland. Reference was made in a previous chapter (p. 124) to the extremely ancient system of hills and valleys that is now being uncovered by the denudation of the Torridon sandstone in the west of Sutherland and Ross-shire. Again, some of the Highland valleys are in part at least as old as the time of the Old Red Sandstone. The line of the Great Glen is one of these. Others of younger date are found in the Southern Uplands, such as the upper part of Lauderdale, with its Upper Old Red conglomerates, and the valleys of the Annan, Moffat, and Nith, with their Permian breccias. It is not, therefore, as if we could start from a definite ascertained point in geological time, in an attempt to trace out the history of the valley-systems of the country. The geography becomes more and more uncertain the farther back we try to follow it. But the main features in the history of its development can be satisfactorily made out.

It is obvious that if, after a land-surface has been so deeply buried under sedimentary deposits that all its topography is entirely concealed, the area should be raised once more into land, the new drainage-lines might have little or no reference to the old ones. They would be determined by the inequalities of surface of the overlying mantle of sedimentary material, and might therefore be wholly independent of any relation to the geological structure of the rocks lying below that mantle. Slowly sinking deeper and deeper into the land, they might eventually reach the older rocks, but they would keep in these the lines of valley that they had followed in the overlying deposits. In process of time, the whole of these later deposits might be denuded from the area. The valleys would then be seen running in utter disregard of the geological structure of the rocks around them, and there might even remain no trace of the younger formations on which they began, and of which the surface-inequalities guided their

excavation. Now this stage also has probably been reached in the history of the valleys of Scotland. It is best exhibited in the southern half of the kingdom; but we probably see examples of it in Highland valleys which, regardless of the structure of the rocks now visible at the surface, may have begun to be eroded when these rocks were covered with a cake of Old Red Sandstone which has since been removed.

Looking at the present topography of the country, we naturally think of it as a completed work—a piece of sculpture which has taken long ages for its elaboration, but which now stands in finished symmetry of proportion and beauty of detail. But the process of carving is manifestly still in progress. Instead of appearing at its close, we look at it when it has still, perhaps, more to accomplish than has yet been done. With the exception of the ice of the Glacial Period, the same powers of waste are still at work before us, and in watching their progress we see exemplified the same kind of action which has brought mountain and glen to their present forms, and which may be destined in the long ages of the future to continue until the last relics of the old table-land have been effaced, and even until mountain and glen have alike disappeared.

The process by which the ancient table-lands of the country have been trenched into the present system of valleys and confluent ridges is most instructively displayed among the higher mountains. In these elevated regions vegetation is scanty, and the naked rock is thus left exposed to the action of the elements. The rainfall is more copious than on the lower grounds, and the steeper declivities give the descending torrents enormous erosive power. The frosts, too, are keener and more lasting, while the variations of temperature from day to day are greater. Hence erosion proceeds at an accelerated pace. The long screes or talus-slopes at the foot of every crag and cliff bear witness to the continual waste of the mountain-

sides.[1] As the head-waters of a river cut into the ridge wherein they take their rise, they lengthen their valley. The valley creeps backward into the very core of the mountain, and its origin and progress are sometimes best explained by what may be seen at its upper end. Thither, therefore, should we betake ourselves if we would see Nature still at her task. Throughout the Highlands, thousands of localities might be referred to as suitable for such a visit. Everywhere in rocky glen or on rough mountain-side we may descry

> "Some tall crag
> That is the Eagle's birthplace, or some peak
> Familiar with forgotten years,—that shows
> Inscribed, as with the silence of the thought,
> Upon its bleak and visionary sides,
> The history of many a winter storm." [2]

Nowhere can a better illustration of this universal waste be found than among the deep glens and corries around the flanks of Ben Nevis. If the observer be sure of foot and steady of eye, let him ascend that mountain, not by the regular track, but up the long and almost equally lofty ridge of Carn Mor Dearg (the big red cairn), which lies to the east, and thence along the narrow and somewhat perilous col which circles round to the south-eastern front of the great Ben. The ascent lies first among heathery slopes, channelled with brooks of clear cold water, and roughened with grey, worn, and weathered hummocks of schist and granite. Blocks of granite of every size cumber the ground, standing sometimes on rocky knolls, sometimes half buried in morass. Slanting up the mountain, the observer has leisure to remark, as he crosses streamlet after streamlet, that their channels often run in deep groves cut out of the solid unfractured rock. He finds them

[1] Mr. Harker believes that in the mountainous tract of Skye these screes go back to the Glacial Period, and that they are but little added to now. *Geol. Mag.*, 1899, p. 485.

[2] Wordsworth, *Excursion*, book i.

grow fewer as he rises.[1] On the slopes, too, the boggy peat and shaggy heather begin to give way to long streams of angular granite blocks, among which the scanty vegetation is at last reduced to mere scattered patches of short grass and moss, with here and there a little alpine plant. A wilderness of debris now covers the scalp of the mountain. The solid granite itself cannot be seen through the depth of its own accumulated fragments; but when the crest of the height is gained, the rock is found peering in shattered knobs from amidst the ruin. This narrow mountainous ridge is then seen to rise between two profound glens. The north-eastern glen is crowned with a rampart-like range of pink-hued granite cliffs, from which long courses of debris descend to the bottom. The glen that lies far below on the south-western side is overhung on its further declivity by the vast, rugged precipice of Ben Nevis, rising some 1500 or 2000 feet above the stream that wanders through the gloom at its base. That dark wall of porphyry can now be seen from bottom to top, with its huge masses of rifted rock standing up like ample buttresses into the light, and its deep recesses and clefts, into which the summer sun never reaches, and where the winter snow never melts. The eye, travelling over cliff and crag, can mark everywhere the seams and scars dealt out in that long warfare with the elements of which the whole mountain is so impressive a memorial.

But, passing from the contemplation of the glens on either side and their encircling ramparts of rock, let the observer pick his way southward along the mountain of which he has now gained the top. He will soon find that from a somewhat rounded and flattened ridge it narrows into a mere knife-edged

[1] The highest spring noted by Petermann on the flanks of Ben Nevis was at a height of 3602 feet, or 766 feet below the summit. A spring on Ben Aulder, one of the highest of the Grampians, was found by the same observer to be 3650 feet above the sea (*Edin. New Phil. Jour.* xlvii. 316). A well fed from melted snow supplies the Ben Nevis Observatory, 64 feet under the top, but fails after a fortnight of dry summer weather.

crest, shelving steeply into the glens on either side. It is sometimes less than a yard broad, and as it is formed of broken crags and piles of loose granite-blocks, it affords by no means an easy pathway. The rock here, as usual, is traversed with abundant joints. Of these the rains and frosts have made good use, and the result has been to shatter the summit of the ridge, and strew the slopes far below with its ruins. The process of waste may be seen in all its stages. In one part, the solid granite is only now opening its lines of joint, in another these lines have begun to gape, giving the rock the appearance of rude uncemented masonry. The severance of the joint-faces can be traced through its successive phases, until the sundered mass has fallen over, and lies poised on a ledge below the crest,

> "As if an infant's touch could urge
> Its headlong passage down the verge."

So narrow is the edge of the ridge in some places that a single block of granite might split into two parts, of which one would roll crashing down the steep slope into the valley on the left hand, while the other would leap to the bottom of the glen on the right. In this sharp form the ridge divides, one arm sweeping round the head of the glen on the north-east side, while the other circles westwards to the shoulders of Ben Nevis.

A more impressive lesson of the waste of a mountain-side and the lowering of a mountain-top could hardly be found. The narrow ridge is a mass of ruin, like the shattered foundations of an ancient rampart, and its fragments have been thickly strewn on the steep declivities below. The larger pieces lie, as a whole, nearest the crest, though many a huge block has toppled down into the depths of the glens. When detached from the solid granite, they still remain a prey to the same ceaseless wear and tear. Rain, frosts, and snows split them up yet further, and then, as they slowly tumble over each

other in their downward course, they become by degrees smaller, though still retaining their dry, verdureless surface. At last, broken up many times in succession, they find their way down into the stream that threads the bottom of the glen. There, chafed against each other and the rocky channel, they are rolled into shingle and gravel. At last, in the form of fine silvery sand, the waste of the far granite peaks is either spread out in the quiet reaches of the stream, as it winds through the valley, or hurried thence by floods, and swept out into the Atlantic waters of Loch Eil. The various agencies of erosion thus work steadily in concert. Those that wear down the flanks of the mountains cast no more debris into the streams than these can in the end sweep away. Hence each glen is insensibly widened and deepened, and each mountain, as it decreases in circumference and in height, silently proclaims,

> "The memorial majesty of Time,
> Impersonated in its calm decay."

It is amid such scenes as these that we can best realise the characteristics of the "corries" of the Highlands. The loftier and more precipitous heights generally have their upper slopes scarped into these steep recesses. The process of excavation seems to have been mainly carried on by small convergent torrents, aided of course by the powerful co-operation of the frosts that are so frequent and so potent at these altitudes. Snow and glacier-ice may possibly have had also a share in the task. No feature in Highland scenery is more characteristic than the corries, and in none can the influence of geological structure be more instructively seen. Usually the upper part of a corry is formed by a crescent of naked rock, from which long screes of debris descend to the bottom of the hollow. Every distinct variety of rock has its own type of corry, the peculiarities being marked both in the details of the upper cliffs and crags and in the amount, form, and colour of the screes. The corries in the great bosses of

granite (Figs. 54 and 57, see also Fig. 12), in the Torridon sandstone mountains of the north-west (Fig. 61), in the soft horizontal yellow sandstone of Orkney, in the gabbro of Skye, in the Silurian grits and shales of the southern counties (Fig. 93), may be cited as examples of this diversity of type. All the Scottish corries have been occupied by glaciers: hence their bottoms are generally well ice-worn or strewn over with moraine-stuff. Not infrequently also a small tarn fills up the bottom, ponded back by a moraine (Figs. 54, 92). It is in

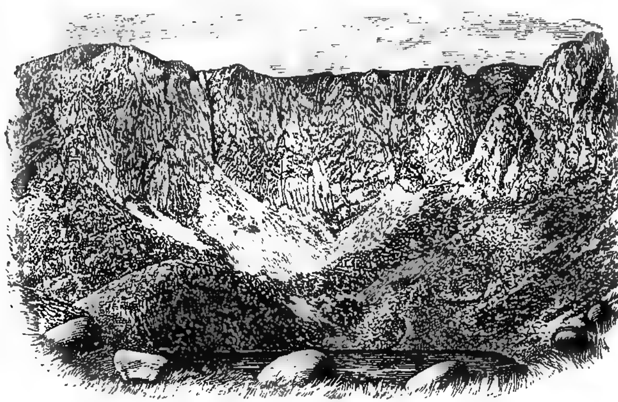

FIG. 54.—Corry on northern front of Lochnagar. Granite cliffs, with screes at the base, descending to a lake which is encircled with glacier moraines.

these localities that we can best observe the last relics left by the glaciers that once overspread the country.

The proofs of enormous and comparatively rapid disintegration, which the loftier mountain solitudes present to us, appeal powerfully to the imagination. They compel the admission that, during a period of sufficient vastness, the sub-aërial agents of waste could carve out glens without the aid of subterranean convulsions. In the scenery around Ben Nevis, there is no evidence of any open fissures or dislocations to which the glens could have owed their

origin. On the contrary, these deep, narrow valleys are crossed at their upper ends by the precipitous junction of their sides, and the connecting wall of granite, though seamed and cracked by the weather, shows no trace of subterranean fracture. Natural, therefore, as the impulse undoubtedly is, in presence of such impressive scenes, to refer these profound concavities to the sundering of the sides of fissures, a little examination of the ground and reflection on the conditions of the problem will assure us that no subterranean dislocation will explain all that we see. The two deep glens to the east of Ben Nevis are separated by the narrow granite ridge of Carn Mor Dearg already described; if one of them had been opened by a rending of the mountain, the expanding of its sides would either have effectually prevented the other from being similarly rent, or would have closed it up had it been already formed. And if it be contended, in answer, that the two narrow open chasms might have been produced by underground movements, and afterwards enlarged by running water and the other powers of erosion, such an hypothesis would really assign most of the work to these gentle agencies. Not only so, it might necessitate the admission that every Highland mountain from which glens diverge is an independent focus of disturbance—an idea disproved by the general geological structure of the Highlands, and especially by that of the plateaux of nearly level Torridon sandstone and Tertiary basalt. The radical error of such an explanation lies in the fact that it assumes the present surface of the country to be, approximately at least, the same as that which witnessed the supposed dislocations to which the glens are attributed. It thus ignores the vast denudation which the whole of that region has undergone. In looking at the disposition of the Highland glens and straths, their winding course, their orderly system, and their complete subservience to the drainage of the country, it seems hard to see how any one

can now call in question the conclusion that the valleys have been made by sub-aërial waste.

If the reader will take a map and consider with attention the arrangement of the Highland glens and straths, he will remark, I think, that two systems of valleys can there be made out (see the map in Plate I.). Of these, the one has a general trend from north-east to south-west, the other from north-west to south-east. Between these two systems there are many intermediate examples; nay, the same valley may sometimes incline to the one and sometimes to the other. But even with such doubtful forms, the two main systems remain tolerably persistent. As illustrations of the north-east and south-west, or longitudinal valleys, reference may be made to the Great Glen, Lochs Carron, Shiel, Linnhe, Fyne, Awe, and to the valleys of the Findhorn, Spey, and Loch Tay. The north-west and south-east, or transverse valleys, are conspicuously seen in Sutherland, Ross, Inverness, and Argyll, and along the southern margin of the Highlands from the coast of Kincardineshire to the Clyde.

As I have stated above, the transverse depressions would inevitably be those chosen by the drainage that flowed off from the main axis of the country or of each region. As the general trend of the geological structure-lines of the Highlands runs from south-west to north-east, and as that would most probably be the direction of any original hollows of the land, longitudinal valleys would naturally be formed in that direction, and would receive and carry seaward the waters of the transverse valleys draining into them. In the longitudinal series, the flow of water is guided by geological structure, either originally manifested at the surface or revealed during the progressive degradation of the land. Sometimes the determining cause of the direction of erosion has been a line of dislocation. Of this relation the most remarkable example in Britain is supplied by the Great Glen. This singularly straight depression coincides with a line of fracture which

appears to be of great geological antiquity, and to have been again and again subjected to disturbance and displacement. More frequently, the longitudinal valleys have had their position defined by the plications of the rocks, which maintain a general north-east and south-west trend. In the other or transverse class of valleys, the line of direction is independent of geological structure, and crosses irregularly the strike of the rocks, according to the readiest route the water could at first find down the slopes of the ridges.

In the evolution of the topography of a country, there is no more significant part than the history of the watershed. Where that feature coincides with the structural axis of the country, we may legitimately infer that it has been determined by the movements which produced that axis. Where, on the other hand, it wanders about in utter disregard of geological structure, it evidently was determined before that structure could have been exposed at the surface, and perhaps upon an overlying mantle of rock which has since been stripped off. The watershed of Scotland presents some interesting problems to the geologist. That part of it which traverses the Highlands consists, as already indicated (p. 116), of two distinct portions. One of these runs southward from Cape Wrath to the wilds of Knoydart, and for that long space coincides pretty closely with the geological strike. It then turns sharply eastward to the line of the Great Glen between Lochs Lochy and Oich. The other portion of the watershed shows a contrasted disregard for geological structure. Starting from the line of the Great Glen, it sweeps round the head of the Spey valley and descends into the valley above the head of Loch Laggan. Here it presents one of the most singular features of its course. Between the Pattack Water, which flows westward, and the Mashie, which flows to the east, lies a flat peat-moss, the surface of which is about 850 feet above the sea. Through this moss the watershed of the country runs, and

then, with a curving southerly course, it passes the west end of the Moor of Rannoch and the Brae Lyon mountains to Crianlarich, strikes thence across Ben Lomond, traverses the great boundary fault, and enters the Midland valley. The farther course of the general watershed of the country may be traced on the map over the Campsie Fells into the wide Lowland valley, whence, after skirting the south-western parts of Linlithgow and Midlothian, and striking across the Pentland Hills, it runs into the Southern Uplands between the valleys of the Clyde and Tweed, crossing the Hartfell heights, from which it sweeps across to the Cheviot Hills.

To the west or left side of the line of water-parting the drainage flows into the Atlantic; to the east or right side it enters the North Sea. This line, it will be seen, runs irregularly across the course of the main hill ranges, just as the watershed of Europe, for example, from Gibraltar to St. Petersburg, sweeps in a widely-curving line athwart the chief mountain-chains. Owing to the steepness of the west side of the island, the line, as we have seen, keeps much closer to the Atlantic than to the North Sea. Hence by far the larger area of the country is drained into the latter basin. In the northern or Highland half of Scotland, no river of any notable size enters the Atlantic, while on the east side, the Spey, the Dee, the Don, the Tay, and a number of smaller, but still considerable, rivers carry the drainage of the mountains to the sea.

On the western side of the watershed, as it runs down Sutherland, Ross, and Inverness-shire from Cape Wrath to Loch Quoich, the transverse system of valleys is singularly well shown. Almost every great valley that enters the sea along that belt of country comes down from the south-east, and has its seaward portion filled by the tides of the Atlantic. The only marked exceptions are Lochs Kishorn, Carron, and Alsh, which belong to the longitudinal or north-easterly system of valleys. In Loch Torridon there is an approxima-

tion to a union of the two series; for the long valley that comes across from Kinlochewe enters Upper Loch Torridon from the north-east, and not until the mouth of that loch is reached does the fjord turn into the prevailing north-westerly course. So at the head of Loch Duich, the dark alpine defile of Glen Shiel opens from the south-east, while another glen comes down from the Bealloch of Kintail on the north-east, and the two valleys unite at a right angle to form Loch Duich.

It is deserving of remark that in the hundred miles of rugged country from Loch Eribol to the Kyles of Skye, every one of those deep transverse valleys crosses the line of the gigantic displacements by which the rocks have been so profoundly modified. Yet they pursue their seaward course without sensible modification, and it is only by careful examination of the ground that the actual position of the great thrust-planes of the region can be fixed.

In the South-western Highlands, the influence of geological structure is manifested by the remarkable predominance of longitudinal valleys. Loch Linnhe, Loch Awe, Loch Fyne, and Loch Long are conspicuous examples, but the same relation is revealed by many smaller valleys. The long narrow sea-lochs of Craignish, Swene, Killisport, and Tarbert have been cut out along bands of schist and slate, which all run from south-west to north-east; and even the direction of the little creeks and headlands and the form of the islands have been largely determined by the same cause. This is the reason why, along that part of the coast, island, promontory, bay, and sea-loch seem all ranged in parallel lines bearing towards the south-west.

In the wide tract of hilly ground lying between the line of the Great Glen and the eastern sea-board of the country, the valleys exhibit a curious intermixture of the transverse and longitudinal types. It is as yet impossible to give any satisfactory explanation of this intermixture, for the evidence that might have been available for the determination of the question has been destroyed by the prolonged denudation of the country.

Many well-marked transverse valleys occur in that region, and their relation to the general axis of the country is clear enough. The river-valleys of Forfarshire supply good examples. But in innumerable cases the streams neither flow in direct transverse lines nor yet in a longitudinal direction, but wander to and fro across the strike of the rocks, with which the trend of these valleys has obviously nothing to do, as if the drainage had been determined on a surface of Old Red Sandstone or of some later formation under which the ancient schists had been buried.

The valley of the Dee, for instance, is neither properly a longitudinal nor a transverse valley, though more of the latter than of the former. But perhaps the most singular example of a defiance of any relation to lines of axis or geological structure is to be found in the case of the Tay. This important river rises at the back of the lofty mountains that tower above the head of Loch Fyne. First it flows in a transverse course down Strath Fillan. It then turns into a longitudinal valley which follows a long north-easterly line through Glen Dochart and Loch Tay, until it bends sharply round into the transverse valley of the Tummel. Thus the drainage, which flows for many miles through the mountains towards the north-east, is turned back at a right angle to its previous course, and carried to the south-east, out of the Highlands and across the great boundary fault into the wide plains of Strathmore.

If one may venture to offer a possible explanation of the history of these valleys, I may suggest that the transverse depression of the Garry and Tay was defined at a very early period, before the now visible geological structure had begun to play a large part in guiding erosion. This valley comes down from the heart of the mountains and passes away to the south-east, like those of the neighbouring Forfarshire rivers. It thus follows what would be at first the natural descent of the water by the shortest and readiest route from the high grounds to the sea. The long valley of Loch Tay and Glen Dochart, on the

other hand, has been excavated along an irregular flat anticlinal axis or fold of the quartzites and schists.[1] But Glen Garry had already been deepened sufficiently to carry off all the drainage that might come from any longitudinal valleys. These valleys, therefore, could not cross it, but must needs pour their waters into it, and help in this way to increase the rapidity of its excavation.[2] To the south-west of the valley of the Garry, Tummel and Tay, a number of short valleys or depressions run parallel to it across the ridge of hills between Loch Tay and the Lowland border. Some of these, like Glen Ogle, pass completely across this ridge, and on the north-west bank of the Loch Tay valley they find their counterparts in depressions which trend to the north-west towards Rannoch. It almost seems as if these depressions once ran south-eastward, across what is now the deep hollow of Glen Dochart and Loch Tay, that hollow having since been gradually cut out, so as to sever those transverse valleys and divert their drainage in great part into its own channel.

I believe that, as above suggested, some of these anomalies in the trend of the valleys are not to be explained by reference to any rock-structures now exposed at the surface, but that they point to the drainage-lines having had their trend determined before the schists were uncovered, and when this district was still encased in a cover of Old Red Sandstone, of which only a mere ragged fringe is now to be found along the Highland

[1] The coincidence of a valley with an anticlinal axis may perhaps be traceable to an actual fracture of the strata along this line of severe tension. Not that the present sides of the valley are the sides of the fracture, nor even that there was ever an open fissure at the surface at all, but that after the removal of a great mass of rock by the sea, and other denuding agencies, the crack still gave rise to a feature above ground and guided the sub-aërial forces in their work of erosion.

[2] The Memoir, by my old friend and colleague J. B. Jukes, "On the River-valleys of the South of Ireland," was the first endeavour to work out the history of a valley-system, and deserves the careful study of all who would follow the literature of this subject. It will be found in the *Quarterly Journal of the Geological Society*, xviii. (1862).

borders. The lines of erosion traced by the rivers in this upper mantle of rock would, of course, have no relation whatever to the arrangement or contour of the schists still deeply buried below. Once traced, they would gradually sink deeper in the Old Red Sandstone, and at last would reach and continue their downward progress in the older platform of schists.

In Chapter II. some account was given of the variety of form assumed by water-channels: how sometimes the stream runs in a wide open valley, and at other times is confined within the narrow walls of a mere chasm. I endeavoured to show that these contrasts could be explained by geological structure, and by variations in the resistance offered to erosion by the rocks exposed to it.

A brief study of the river-valleys of Scotland will suffice to convince the observer that these drainage-lines were already in existence before the Ice Age, and that when the glaciers disappeared, the valleys were left so largely choked up with boulder-clay, sand and gravel, moraine-stuff, or other kind of "drift," that the rivers were often prevented from reoccupying their old channels, though nevertheless following the general line of the valleys. They still to a very large extent wind about in courses which they cut for themselves out of the glacial detritus, and have not yet reached the solid rock below. It will be found that where they have eroded gorges in which they now flow, this erosion has been performed for the most part since the Glacial Period, and has arisen because the streams have been deflected upon solid rock, owing to the irregularities of the surface left by the drift deposits.

A large river winding down a wide valley, still in great part covered with drift, leaves a succession of terraces to mark the gradual downward progress of its channel (p. 33). Of all the Scottish rivers, none displays this evidence of river-history so remarkably as the Spey. During the height of the Ice Age an enormous body of ice must have drained from the surrounding mountains into Strath Spey, and when the glaciers were

creeping back to their sources, copious streams must have been discharged from the melting ice. The moraine-stuff abundantly supplied by the glaciers was rolled along and reassorted by the river, and now forms a striking feature in the valley all the way from the mouth of the Truim to Nethy Bridge. A careful study by Mr. Hinxman of the terraces of this material has shown that while they have a slight general inclination down the valley, this slope is by no means uniform, seeing that, after falling 70 feet on the north or left side, a terrace rises again as much as 20 feet, while on the southern or right side the corresponding terrace, after falling 80 feet, again mounts to within 20 feet of its original height. These platforms of detritus are thus hardly either river-terraces or lake-margins. Their component well-stratified sand and gravel probably never stretched completely across the valley, but were laid down between the hill-slopes and the edge of the slowly shrinking glacier which still occupied the centre of the strath. The marshy meadows and lakes now remaining may thus mark hollows in the bed of the glacier, while the "kettle-holes" or tarns scattered over the surface of the detritus may indicate where detached masses of ice melted away. The co-operation of ice is further shown by the numerous large subangular blocks of granite scattered over the ground.[1]

The old terraces of the Spey continue to be a marked feature of the scenery of the river, even after the constriction of the valley between Grantown and Craigellachie. They come out in strong development above and below Rothes. The Glen of Rothes, which extends between the Spey and the low country about Elgin, likewise contains a remarkable display of similar bold and high alluvial platforms. The stream which now flows in this glen is little more than a mere ditch, and cannot be supposed to have formed those magnificent terraces. It would almost seem as if the ample waters of the Spey had at one time found their way through Rothes Glen and entered the

[1] *Summary of Progress of the Geological Survey* for 1897, p. 149.

sea somewhere in the neighbourhood of the present mouth of the Lossie.

River-gorges form undoubtedly some of the most picturesque features in the scenery of the Highland valleys. Their characteristic varieties of aspect can be traced back to the guiding influence of the structure of the rocks in the progress of erosion. By much the most imposing ravines are those which have been excavated in the Old Red Sandstone along the borders of the Highlands. The massive conglomerates and thick-bedded sandstones, with their clean-cut lines of jointing, afford peculiarly favourable conditions for the excavation of long, narrow chasms, where the drainage, laden with debris, escapes from the more rapid slopes of the interior. On the north side of the Highlands, a series of remarkably striking ravines lies in the strip of Old Red Sandstone along the west side of the Cromarty Firth. Perhaps the most singular of these is that of the Alt Graat—a chasm about 110 feet deep, and at the narrowest part only 17 feet across the top, wherein the scooping action of the water, in cutting down the massive conglomerate, is conspicuously visible. This remarkable gorge is fully five times deeper than it is broad—a ratio very unusual among the river-ravines of this country, which are generally broader than deep.[1] It has been worn out of the conglomerate across the lines of joint, and is an excellent example of unaided aqueous erosion. The large smooth semicircles that have been scooped out of the massive conglomerate are partly shown in Fig. 55. That this gorge has been entirely excavated since the Ice Age cannot be doubted. Immediately above it the valley expands and is filled with boulder-clay, which, burying the old channel, has driven the stream to cut a new one through the barrier of conglomerate.

The ravines of the Beauly, Nairn, and Findhorn are on a larger scale. That of the Nairn displays in the most picturesque

[1] These measurements were taken for me by my colleague in the Geological Survey, the late Mr. Hugh Miller.

manner the scenic peculiarities of the coarse Old Red conglomerates. It has been dug through the conglomerate, and for some way in the underlying schists, its total depth sometimes reaching 130 feet or more. This narrow tortuous cañon

FIG. 55.—The Black Rock of Novar, Cromarty Firth. A chasm eroded by a stream in Old Red Conglomerate.

shows concave and corresponding convex walls on either side, with old potholes half cut away at various heights far up the precipices.

More striking still are the gorges that have been dug out of the Old Red Sandstone along the southern margin of the High-

lands in Perthshire and Forfarshire. That of the Ericht, above Blairgowrie, is a true cañon eroded in the conglomerate, and averages about 150 yards in width, by 150 to 180 feet in depth. As will be observed in the woodcut (Fig. 56), the parallel lines of joint, along which the rock splits, enable the ravine to maintain the verticality and parallelism of its walls. Farther east the gorges of the Isla and the Esk likewise furnish excellent illustrations of the peculiar aptitude with which the Old Red Sandstone lends itself to picturesqueness of detail in landscape.

Even in the little separate basins of Old Red Sandstone which are dispersed over the Northern Highlands, the typical characteristics of the river scenery in this formation are maintained. Thus, the gorge of the Ailnack above Tomintoul forms one of the most impressive ravines anywhere to be seen in Scotland. It has been eroded to a depth of some 150 feet through coarse conglomerate (*ante*, p. 159) and the underlying schists. That this excavation has been done since glacial times is indicated by the morainic gravel which is spread over the surrounding country and caps the cliffs on either side of the gorge. Indeed, we can see that the rate of waste must be distinctly appreciable, for landslips are from time to time taking place on the sides of the ravine. When I visited the scene in 1884, I observed that portions of the fence erected at the top to prevent accidents had been carried down by a recent fall, and were lying among the ruin at the bottom. The same district supplies much suggestive material for a history of river-action since the Ice Age. Thus, the Avon, descending from the heart of the highest Grampians, has not always been able to resume its pre-glacial channel, but has been turned aside by accumulations of drift and forced to carve for itself new ravines in solid rock. Below Tomintoul it has cut a picturesque ravine in limestone, having probably been driven to do so by the opposing ridge of drift on which the village stands. If this barrier were removed the river would flow into

the valley of the Conglas Water and join its present channel

FIG. 56.—Gorge of the Ericht, above Blairgowrie. From a photograph taken by Mr. G. Barrow of the Geological Survey.

lower down. Very little topographical change would be needed

to effect this diversion. On the lowest part of the ridge a flat peat-moss lies on a terrace between the two streams.

Among the crystalline schists of the Highlands, the cañon or steep-walled type of river-gorge is much less frequent, obviously because, as a rule, there is much less regularity of structure, and especially of joints, among these rocks. But where the schists are not much crumpled, and are traversed by regular parallel joints, they supply examples of deep, narrow ravines. Perhaps the best instance in the Highlands of this feature is to be seen in the course of the River Broom, which falls into the head of Loch Broom. The flagstones (Moine-schists), which there dip in regular beds at low angles towards the south, are cut by well-defined parallel joints, and the little river has excavated in them a profound chasm that terminates at its upper end in a waterfall, across the top of which the strata can be traced in unbroken sequence from side to side.

Allusion has already been made to the frequent association of gorges with alluvial plains or lakes above them (p. 175); but some further account of this feature may here be given. Where a valley contracts and its stream flows through a rocky defile, there is commonly an expansion of the valley above the ravine. This association is usually explained by a difference in the relative hardness of the rocks eroded by the stream. The harder masses resist more, and are therefore less rapidly worn down. Where they cross a valley, therefore, they retard the excavation, while the softer rocks lying farther up are more rapidly wasted. But as the stream cannot lower its bed below the level of the barrier of hard rock, it attacks the side of the valley and thus widens it out, while at the same time it is sawing down the rocky barrier and making a ravine. In districts of comparatively simple geological structure, where, for instance, soft shales alternate with courses of hard sand-stone, the truth of this explanation can be readily seen. But it is not so easy to apply it in many Highland valleys where

there is no very evident reason in any apparent difference in the rocks to account for the alternate expansion and contraction. Instances of this common feature will readily occur to any one who is familiar with Highland scenery. As an easily accessible locality, I have already cited Glen Falloch, above the head of Loch Lomond, in which between that lake and the watershed some four or five examples may be seen in the course of six or seven miles. Other excellent examples may be noticed in Glen Spean, above the Bridge of Roy. One of these is conspicuous just above the great gorge at Achluachrach (field of rushes), whence a broad alluvial plain stretches for almost two miles to near Inverlair, where it gives place to another gorge in the hard massive schists. Above this second ravine lies another alluvial plain with lateral terraces. A large moraine that has been thrown across the valley has turned the stream aside and compelled it to saw out a narrow gorge in the schists. Meadow-like expansions of this kind in the glaciated regions were probably ice-eroded lake-basins, which have since been silted up. Reference will be made in a later chapter to the occurrence of glen-lakes above gorges in many parts of the Highlands (p. 263).

Among the high grounds, where disintegration proceeds apace, the gradual narrowing of ridges into sharp, knife-edged crests and the lowering of these into cols or passes can be admirably studied. Two glens that begin opposite to each other on the same ridge, gradually cut back their respective corries until only a sharp crest separates them. This crest, attacked on each front and along the summit, is lowered with comparative rapidity, until in the end merely a low col, pass, or balloch may separate the heads of the two glens. The various stages in this kind of demolition are best seen where the underlying rock is of granite or some similar material which possesses considerable toughness, while at the same time it is apt to be split and splintered by means of its numerous transverse joints.

The district around Ben Nevis again furnishes us with good

illustrations of this process in the sculpture of the land. The narrow crest of granite referred to earlier in this chapter forms a kind of shattered partition wall between two glens that run northward and one that stretches southward. This intervening and lessening partition is doomed in the end to be wholly removed, and then one long glen will flank the east side of Ben Nevis, with perhaps a low, scarcely perceptible watershed marking where the narrow transverse ridge now rises. The granite mountains of Arran likewise present good examples of passes in their various stages of progress (Fig. 57). Thus, the glens on either side of Goatfell are separated by crests of splintered, crumbling granite, which are manifestly being lessened in height and width. The crest that once joined Caisteal Abhail and Cir Mhòr has been reduced to a high rocky col separating the head of Glen Sannox from a tributary of the Iorsa. But the craggy ridge that intervened between the head of Glen Rosa and Glen Sannox has been cut down into a low craggy pass, known as "the Saddle."

Such I believe to have been essentially the origin of the numerous long Highland valleys in which there is a central inconspicuous point whence the water flows in opposite directions. In the lower parts of the country, the waves of the sea during a time of depression, and among the hills, the grinding of glaciers during the Ice Age, may have lent their aid in completing the levelling of the barrier between the advancing glens. But the main part of the work was no doubt done by sub-aërial disintegration and erosion.

Most of the high roads across the Highlands are carried through such continuous valleys, where the watershed is often so imperceptible that it may be crossed unawares, even by one who is on the outlook for it. The road from Loch Carron, across Ross-shire to Contin, seems to run along one great transverse valley, bounded on either side by lofty hills; yet if the tourist watches the flow of the water, where, a few miles to the south-west of Auchnasheen, among old glacier moraines,

the road reaches a height of rather more than 600 feet above

FIG. 57.—View in the granite tract of the Island of Arran, to show the formation of corries and ballochs. The cone in the centre is Cir Mhòr (Big Comb), that to the right Caisteal Abhail. In the far distance across the ridge of Cantyre are seen the quartzite cones of Jura.

the sea, he will observe that the streams flow off in opposite directions, one set turning eastwards, and falling into the

Cromarty Firth, the other bending south-westward, and joining the Atlantic in Loch Carron. There is no mountain, hill, or ridge, not even a marked mound, to make the watershed: the valley of Loch Carron ascends inland, and imperceptibly merges into another valley, which descends to the sea on the opposite side of the island. The waters of a spring at the summit level of the road may be turned with the hand either to the eastern or western sea. In like manner, the post-road from Arisaig to Fort-William passes through a long valley which connects the head of Loch Aylort with the head of Loch Eil. Another transverse glen runs from the banks of Loch Fyne, across Cowal to the head of the Holy Loch, and contains the long, narrow fresh-water lake known as Loch Eck. The great north road from Perth to Inverness runs up the valley of the Garry, and thence across the watershed of the Grampians into Glen Truim, the connection between the two valleys being made by the Pass of Drumouchter—a wild glen in which, among the rubbish-mounds of old glaciers, the water flows partly northward down Glen Truim, and partly southward down Glen Garry. The lonely pass of Corryarick, through which, amid piles of glacier moraines, the old decayed military road runs, at a height of 2507 feet above the sea, from the head of Strathspey to Fort-Augustus, may be cited as another example and as one of the most remarkable and least visited routes in Scotland.

There is another kind of valley in the Scottish Highlands deserving of special notice in an inquiry into the origin of the scenery of the country. To a small extent on the east coast, but on a great scale along the western side of the island, the sea runs inland in long, narrow inlets. These sea-lochs, which form so conspicuous an element in the topography, are true fjords, like those that indent the western coast of Norway. Each of them terminates at the mouth of a glen or strath, and receives there the collected drainage of the interior. No marked line of demarcation can usually be traced between the

land-valley, watered by its brawling brook or river, and the sea-valley, filled with the ebbing and flowing tides (Fig. 58). The grassy slopes or rocky declivities which form the sides of the one, run on to form the sides of the other. If we could depress the land below the present sea-level, and send the salt water far up into these inland glens, they too would become true fjords. If, on the other hand, we could upraise the land, the sea-lochs, emptied of their salt water, would become land-

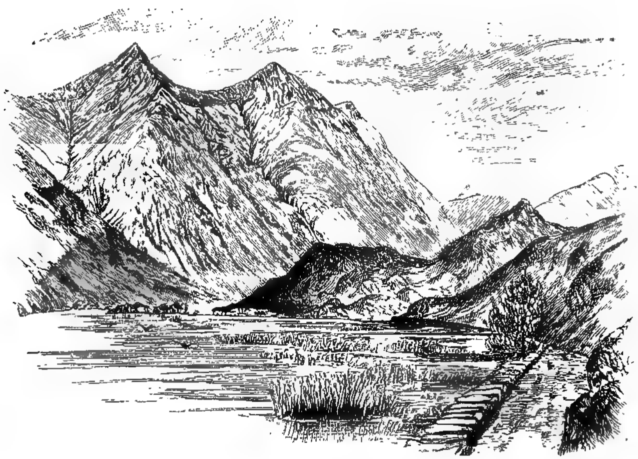

FIG. 58.—Head of Loch Duich. A fjord merging into the valley of Glen Shiel.

valleys, and it might in the end be impossible to say where, at some places, the former limit of the tides had been. In each case, we should see what is in truth one valley, part of it being submerged and part open to the sky.[1]

The indented character of the western coast has been popularly ascribed to the unequal encroachments of the sea. But even a superficial acquaintance with the usual features of these sea-lochs ought to disprove such a notion. For it is

[1] See Sir A. C. Ramsay's remarks to the same effect, in his paper on the origin of lakes.—*Quart. Journ. Geol. Soc.* xviii. p. 185.

well known that the inlets are, as a rule, deep, sometimes much deeper than the sea outside. But the sea, as we have seen, cannot scoop out deep hollows; its erosive power is confined to its upper part, and its tendency is to plane down its shores. Instead of excavating a fjord, it can only level the rocks that are lashed by its breakers or are worn down by the gravel pushed onward by its currents. If the land-valley has been hollowed out by sub-aërial erosion, a like origin must be assigned to the continuation of the same valley under the sea-level. The sea-lochs of the west coast are assuredly not inlets cut out by the waves. They are old glens that have been submerged beneath the sea. They prove that the west side of the island has subsided in a comparatively recent geological period, and that the tides now ebb and flow where of old there was the murmur of brooks and waterfalls, and the sheen of sunlit lakes.

Further evidence of subsidence along the west coast is to be found in the long archipelago that runs from the Butt of Lewis to the south end of Islay. These hundreds of islands are only the projecting parts of ridges like those on the mainland, and the channels between them are submerged valleys. As the Admiralty charts show, if the whole western side of the country were upraised, the "Sounds" and "Kyles" would be turned into straths and glens, undistinguishable in general form and character from those with which we are at present familiar.[1] The association of abundant fjords and islands is thus not accidental. Both these features in the topography have sprung from one common cause.

By way of contrast with the west coast, let us look at the eastern sea-board of the island. The absence of long, narrow winding inlets is there as conspicuous as the scarcity of islands. That side of the country has unquestionably been subjected to movements both of upheaval and subsidence. Its last

[1] Some of the broader features of the sea-floor on the west side of the country are shown on the map in Plate I.

changes, like those of the western coast, have been in an upward direction, but on neither side of the country, and more especially on the west side, has the elevation brought the land up to the level at which it stood before the great submergence that gave birth to our sea-lochs.

If this view of the origin of the western sea-lochs be correct, it is natural to expect that traces of different stages of the submergence should be found: that, as the downward movement of the land went on, some lake-basins in the valleys should have been carried far down beneath the surface of the sea; that others at a higher level should have sunk a shorter distance; and that others should have barely escaped when they had approached within a few yards of the sea-level. Examples of these various steps in the process will occur to those who are familiar with the western coasts. Of the first, Loch Fyne is a notable illustration, as it deepens a little south of Tarbert into a basin 624 feet below the surface of the loch, and shallows northward and southward. If this great fjord were now a land-valley, that basin would be filled with a lake. Of the second stage, Loch Etive forms a good example. This inlet narrows at Connal Ferry, and across the straitened part runs a reef of rocks, covered at high water, but partly exposed at ebb. Over this barrier the flowing tide rushes into the loch, and the ebbing tide rushes out with a rapidity which, during part of the time, breaks into a roar of angry foam. For a brief space of time, there is here a veritable cataract of sea-water. The greatest depth of the loch above these falls is 420 feet; at the falls themselves there is a depth of only 6 feet at low water, and outside the barrier the soundings reach, at a distance of two miles, 168 feet. Loch Etive is thus a characteristic rock-basin, and an elevation of the land to the extent of only 20 feet would isolate the loch from the sea, and turn it into a long, winding, deep fresh-water lake. Of the third stage, where the lake has been brought down close to, but has not quite reached, the present sea-level, Loch Maree, Loch Morar, and Loch

Lomond may be taken as illustrations.[1] If the downward movement were to recommence, these lakes would ere long be turned into arms of the sea.

It is curious to watch the efforts made by the land for the recovery of its lost territory at the head of many of the sea-lochs. At the upper end of Loch Carron and of Loch Broom, for example, the rivers are pushing out their alluvial flats into the salt water, and gradually driving it backward, regaining in this way, step by step, the site over which they once rolled. In other cases, the tides and currents of the sea itself are raising barriers against it. Thus Loch Fyne is nearly cut in two by the long sand-bar thrown up by the tides at Otter. The Gareloch, in like manner, is almost barred across by the similar spit which runs out at Row. In each instance, a powerful tidal current tends to keep the narrow channel open by sweeping fresh accumulations of sediment out to sea.

The eastern sea-board of the Highlands presents a striking contrast to that on the west side of the island. Instead of winding far into lochs and kyles, or beating round peninsulas and islands, the sea there rolls along a coast-line that runs mile after mile in a persistent course, interrupted merely by trifling indentations. It is only in the angle between the shores of Caithness and those of Elgin that inlets occur in any way comparable to those of the west. Beginning at Loch Fleet, on the margin of Sutherlandshire, we pass in southward succession the Firths of Dornoch, Cromarty, Beauly, Inverness, and Moray. These resemble in outline some of the narrow fjords of the west, Cromarty Firth approaching nearest to the western type; but they show many essential points of difference. They are entered by large streams bearing abundant

[1] For the sake of simplicity I have left out of account the later upheavals of the land, which have to a trifling extent restored what the older depression had submerged. Maritime lakes, such as Loch Lomond, must of course have been arms of the sea when the land stood at the level of the 50-feet raised beach, that is, 50 feet lower than it stands to-day.

alluvium, and their shores, low as a rule, are formed not of steep ice-worn rocks, but of raised beaches and slopes of boulder-clay. They have thus a smooth and tame character which is wanting in the western sea-lochs. Moreover, they are, as a whole, shallow, the tide leaving wide flats at low water, and sometimes even forsaking the firth altogether. At Loch Fleet, for instance, advantage has been taken of this feature, and a strong mound having been built across the firth to keep back the salt water, the higher part of the loch has been turned into dry land. Nearly the whole of these firths are conspicuous for the sand-bars at their mouths, which have been thrown up by the tides above high-water mark, and run out from either bank, striving as it were to form a completed barrier against the sea outside. The mouth of the Inverness Firth is a notable example. From the east side, a long low sand-ridge stretches half-way across, and bears Fort-George at its extremity. From Fortrose, on the west side, another spit of the same kind runs out into the middle of the firth, the two bars actually overlapping each other, so that if they lay exactly opposite they would meet and turn the Inverness Firth into a lake. The Dornoch Firth is likewise intersected by a long ridge of gravel extending from the south bank at Meikle Ferry, and with a corresponding but smaller spit a little farther down on the north bank.

The Cromarty Firth perhaps furnishes to the geologist more matter of interesting inquiry than any of the others. At its upper end, where the Contin brings down the drainage of a large tract of Eastern Ross-shire, this noble arm of the sea has been so encroached upon by the advance of the river alluvium, that, as already referred to, several square miles of sandy and muddy flats are laid bare at low water. From these higher shallows, the firth stretches, with a tolerably uniform breadth of rather more than a mile, as far as Invergordon, where it reaches a maximum depth of 70 feet. It then expands into a wider basin, forming the sheltered spacious

anchorage for which the inlet is so well known. This expansion of the firth is not so deep as the narrow channel at Invergordon. But a little to the east of the town of Cromarty, where the channel suddenly contracts to a breadth of less than a mile, it shelves down to a depth of 170 feet, and passing between the two precipitous headlands of the Sutors, enters the open Moray Firth. One who approaches from the east is at once struck with the narrow chasm-like entrance of the Cromarty Firth, cut through a long lofty range of red sandstone precipice. It is wholly unlike the mouth of any other firth in the country, for it is not the seaward expansion of a land-valley, but seems, in some abnormal fashion, to have been broken through a high barrier of hard rock; and, in actual fact, it is an abnormal opening, and not the original mouth of the firth.

To understand the present and the former conditions of this sea-loch, one should ascend the heights behind the town of Cromarty. Looking from the crest of the Black Isle over a scene which the pen and hammer of Hugh Miller have made classic ground to the geologist, we see below us the firth filling the ample basin of Cromarty, creeping over sandy flats in the Bay of Nigg, and turning thence abruptly to the south-east to force its way between the Sutors. The north-west side of the estuary is formed by a gently-sloping declivity stretching towards Tain. The north-eastern side rises into the ridge of the Black Isle, and runs north-eastward through the two Sutors into the long promontory of Tarbert Ness. Though the firth turns abruptly round to pass out between the Sutors, the prolongation of the valley in which it lies is continued from the Bay of Nigg to the Dornoch Firth by the low valley or plain of Easter Ross. Even from a distance it is not difficult to see that this low valley was probably the original outflow of the firth, when the level of the land was lower, and before the opening of the present outlet. From the heights above Cromarty, the eye looks along the north-

ward drift-covered slope of the Black Isle, and if it were not known that the sea flows between the Sutors, it might readily be supposed that the ridge extends in one long unbroken line from the head of the firth away to Tarbert Ness. It could not be suspected that this ridge is actually cut through by the present narrow precipitous opening. If, then, the Cromarty Firth once entered the Firth of Dornoch between Tarbert Ness and Tain, how has it come to join the Moray Firth by so abrupt and narrow an outlet as that which lies between the Sutors?

Here, perhaps, if anywhere, the believers in the efficacy of underground convulsions might make a bold stand. How could the firth, they might ask, quit its old channel and take one so widely different, unless the new outlet had been opened for it by an earthquake shock? The two Sutors seem to

> "Stand aloof, the scars remaining,
> Like cliffs which have been rent asunder,
> A dreary sea now flows between."[1]

It may be impossible absolutely to prove the origin of the deep gorge between the Cromarty Sutors; but it seems to me that there is evidence in the neighbourhood strongly in favour of the supposition that the work has been mainly done by running water. Let the observer cross to the Nigg side of the firth, and traverse the high ridge which is prolonged from the Black Isle. The rocks there are well ice-worn, the moulded knolls and the ice-groovings upon them running in an E.N.E. direction. Passing over to the eastern coast, a line of lofty red sandstone cliff—the continuation of those on the south side of the entrance to the Cromarty Firth—rises from the rocky beach and extends northwards to Shandwick. About a mile south of that fishing hamlet, a depression or valley, running across the ridge, descends into the flat plain

[1] Coleridge's *Christabel.*

of Easter Ross on the west side, and to the edge of the sea-cliff on the east. The bottom of the valley is coated with boulder-clay, through which two runnels, diverging from the low watershed of the hollow, flow in opposite directions. One of them trickles westward into the low grounds between the Bay of Nigg and the Dornoch Firth, the other having a steeper and shorter declivity has cut its way deep into the red sandstone, forming there a ravine which breaks through the cliff and descends upon the beach. The streams are thus busy digging out the valley and working their way backward to each other. The same process must have been going on previous to the Ice Age, for the valley is older than the boulder-clay. Nor can it be doubted, that if time enough be allowed, these tiny rivulets will in the end cut down the ridge, and, especially if aided by a slight subsidence of the land, may allow the sea to force its way to the plains of Easter Ross through a narrow gorge similar to that between the Sutors. The process is another example of the cutting down of mountain passes, and of long nearly level valleys crossing watersheds. Only, in the present instance, the changes are going on close to the sea-level, and it can be readily seen that the later stages of the work may be done by the co-operation of the wild breakers of the northern sea. As I have just said, it cannot be demonstrated that the present outlet of the Cromarty Firth has been opened in this way, but I think no one can watch the effects of the streams near Shandwick without a conviction that the explanation has high probability in its favour.[1] We must remember also that a very slight depression of the land would be enough to bring such low cols as that near Shandwick within reach of the

[1] This excavation, which was begun long before the Glacial Period, may have been greatly helped by the mass of ice that filled up the Cromarty Firth, and, as shown by the striations, slanted across the ridge of the Black Isle. There could not fail to be a great pressure of ice through the gorge between the Sutors. A deep mass of boulder-clay now lies in the bottom and on the sides of that gorge.

waves, and that in this way subterranean movement may have indirectly contributed to the scouring out of the passage.

The greater depth, steepness, and number of the fjords on the west side of the island, may be partly attributed to the greater height and abruptness of the country on that side, and partly also, perhaps, to heavier rainfall and consequently a higher rate of denudation (p. 217). The more extensive submergence of the West Highlands has likewise helped to indent the western sea-board, by allowing the waters of the Atlantic to run far up among the recesses of the mountains, and thus to fill the glens. The east coast, as a whole, is lower and farther from the hills, and its rivers enter the sea, not between the steep sides of rocky glens, but among level or gently undulating lowlands covered with superficial deposits. A submergence of the seaward ends of these river-valleys would not make the coast-line resemble the coast-line of the other side of the kingdom, save only in such parts as the east of Sutherland, where the mountains and the narrow glens come within a short way from the sea-margin. Long narrow sea-lochs, like those of Inverness and Argyll, are thus almost wholly absent from the eastern shores: where they do occur, it is just where the character of the neighbouring ground approaches most to that of the Atlantic sea-board. They are crowded together in the angle between the counties of Caithness and Elgin, where the mountains of Sutherland, Ross, and Inverness come closest down upon the North Sea.

It must not be forgotten that precisely the same kind of diversity between the two sides of the country, but on a larger scale, is prolonged into the Scandinavian peninsula. The west side of Norway, with its thousands of deep fjords and inlets, is a magnified piece of West Highland scenery, and the undulating drift-covered plains of Sweden, with their comparatively unindented coast-line, along the Gulf of Bothnia, recall those

of the east side of Scotland. If we are justified in regarding the sea-lochs of the west of Scotland as indicative of a greater submergence of that side of the country at a recent geological period, we may extend the generalisation into Scandinavia, and conclude that the whole Atlantic sea-board of the north-west of Europe has sunk down at a comparatively late epoch in geological history.

CHAPTER IX

THE HIGHLAND HILLS

If the views expressed in the preceding chapter regarding the origin of the valleys of the Highlands be correct, there are obviously no true mountains in that region. A mountain, if the term is to be used with any definite geological significance, is a tract of the earth's surface which owes its position to a special upheaval of the terrestrial crust, and whose direction, external form, and internal structure bear witness to this upheaval. But no area of high ground in Scotland answers to this definition. When the heights that form the connected ridges or the isolated hills of the country are examined from this point of view they, one and all, proclaim that they are essentially the results of unequal erosion. As I have already stated, they have been left prominent because surrounding masses of rock have been removed from them. So important is the realisation of this fact in the study of the topography of the country that, at the risk of wearying the reader with reiteration, I would again insist on the significance of the evidence that thousands of feet of solid rock have been gradually stripped off the general surface of the Highlands. I have endeavoured to prove that the original forms of the surface of the region in Palæozoic time have entirely vanished, that conjecture is hardly even possible as to what may have been the configuration of the country after the plication and dislocation of the Highland rocks, and that since these early ages the land has been buried under

successive geological formations, which have subsequently been, one after another, removed by denudation. The surface of the region may thus have been reduced more than once to a base-level of denudation beneath the sea. A platform of erosion, cut across the various rocks of a country, may remain with but little change for an indefinite period, if protected under the sea from further abrasion, yet not lying deep enough below the sea-level to receive a permanent or thick deposit of sediment. But if subsidence should intervene, the platform may be slowly carried down into quiet depths, and a thick accumulation of sedimentary materials may be laid down upon it. That this has happened again and again over the site of the Highland hills is made certain by the geological structure of the country. We know that there was a stupendous denudation of the Lewisian gneiss before the deposition of the Torridon sandstones; that these sandstones were in turn extensively eroded before the Cambrian quartzites began to be laid down; and that the Cambrian strata, probably together with a series of Silurian sediments, long after their metamorphism and dislocation, were likewise extensively denuded before being buried under the conglomerates of the Lower Old Red Sandstone. The region was subsequently planed down and partially covered over with accumulations of the Upper Old Red Sandstone. In Carboniferous, Permian, Jurassic, Cretaceous, and Tertiary times similar denudation, depression, and entombment were in progress.

The geologist who realises the true meaning of these statements can only smile when he hears confident reference made to the aboriginal scenery of the Highlands, as if the present hills and glens had retained the forms impressed by subterranean disturbance during Palæozoic time. There cannot be the least doubt that the existing ridges and hills, like the valleys that surround them, are entirely the work of erosion, variously modified and guided by the influence of geological structure. In not a single instance can any so-called mountain in Scotland

be adduced as owing its forms directly to underground movement.[1] Every mountain or hill has been slowly carved out during the general degradation of the whole surface. I have already insisted that there are proofs of gigantic upthrusts of the earth's crust; but the lines of these great movements are not marked by ranges of mountain. On the contrary, the ground that has demonstrably been pushed up is now often lower than the tracts around it; while masses of mountainous ground that tower boldly above the surrounding hills will be searched in vain for any geological structure indicative of special local upheaval.

While it is fruitless to look for the aboriginal topography of the present high grounds of Scotland, we may reasonably infer that the oldest surfaces which are likely to be in any measure preserved or indicated are portions of some of the platforms of erosion which in the long ages of geological history have successively been produced. Fragments of some of these platforms have survived by being protected by the deposits under which they were buried, as in the striking vestiges of a pre-Torridonian land-surface which have been found in Sutherland and Ross-shire (p. 124). I have described at some length the present table-land of the Highlands as a relic of prolonged erosion, and I propose now to ask the reader's attention to some exceptional localities where considerable portions of the general surface of that table-land appear to be still extant.

Allusion has already been made to the remarkable flat-topped moorlands which in the eastern Grampians reach heights of 3000 to 4000 feet above the sea. These lofty plateaux descend, sometimes by craggy precipices, sometimes by steep declivities, into the deep glens that traverse them and separate them into ridges and isolated eminences. Their most familiar

[1] Some of the Tertiary granitic cones, like the Red Hills of Skye, may possibly retain traces of an original *puy*-like form; but they certainly consolidated under a mass of rock which has since been stripped away from them.

example, perhaps, is the top of Lochnagar, where when the level of 3500 feet has been gained, the traveller finds himself on a broad undulating moor, more than a mile and a half long, sloping gently southward towards Glen Muick, and terminating on the north at the edge of a range of granite precipices (Fig. 12). On the other side of the Dee, the top of Ben Macdhui (Beinn na muich dhu, the hill of dark gloom) stands upon nearly a square mile of moor exceeding 4000 feet in elevation.

These mountains lie within the granite area, but not less striking examples may be found among the schists. The mountains at the head of Glen Esk and Glen Isla, for instance, sweep upward into a broad moor some 3000 feet above the sea, the more prominent parts of which have received special names,—Driesh, Mayar, Tom Buidhe, Tolmount, Cairn na Glasha (3484 feet). It would hardly be an exaggeration to say that there is more level ground on the tops of these mountains than in the valleys below.

That these high plateaux are planes of erosion is shown by their independence of geological structure, the upturned edges of the vertical and contorted schists having been abruptly shorn off, and the granite having been wasted and levelled along its exposed surface. They stand out as fragments of an original table-land of erosion out of which the present valley-systems of the Highlands have been carved; though doubtless they have since in the course of ages lost much from their surface as well as from their sides.

If, then, we look upon the present flat-topped heights among the eastern Grampians as fragments of the general surface out of which the present Highlands have been carved, we may trace every step in the gradual obliteration of the table-land and in the formation of the most rugged and individualised forms of isolated mountain. This may best be done by following the ridges westwards. The broad flat summits of Aberdeenshire and Forfarshire gradually give place to narrow ridges and crests which reach their extreme of

serrated ruggedness down Western Inverness-shire and Argyll-shire. In journeying westwards across the tops of the Highland mountains, we pass, as it were, over successive stages in the history of the origin of Highland scenery. The oldest types of form lie on the east side, and the newest on the west. From the larger fragments of the denuded table-land, we advance to ridges with narrow tops, which pass by degrees into sharp rugged crests. The ridges, too, are more and more trenched, until they become groups of detached hills or mountains, such as the peaks of Loch Hourn, Glen Shiel (Fig. 58), Glen Nevis, and Glencoe, and the gnarled craggy summits of Argyll's Bowling Green. These characteristics of West Highland scenery are best seen from some inland summit. An excellent point of observation is the top of Ben Iadain—a hill which has already been described and figured (Fig. 50). From that height the eye can sweep over a wide array of ridges, crests, and peaks from Ardnamurchan on the north, eastwards across Sunart, Ardgower, and Morven, and can catch the summit of Ben Nevis towering in the far distance above every other eminence (Fig. 59). A greater contrast could hardly be found than between this deeply trenched region of hills and the long bare sweep of hill-tops in the Eastern Highlands. The reader may judge of this contrast by comparing the two panoramas depicted in Figs. 40 and 59. A somewhat similar but less marked contrast is traceable in the Southern Uplands between the broad, smooth, moory summits of Peeblesshire and the more rugged and precipitous heights of Galloway.

No satisfactory reason for these contrasts can be found, so far as appears, in geological structure alone. Perhaps the key to them is to be sought mainly in differences of rainfall and consequent rapidity of denudation (p. 211). The western mountains, exposed to the fierce dash of the Atlantic rains, sustain the heaviest and most constant precipitation. Their sides are seamed with torrents which tear down the solid rock, and

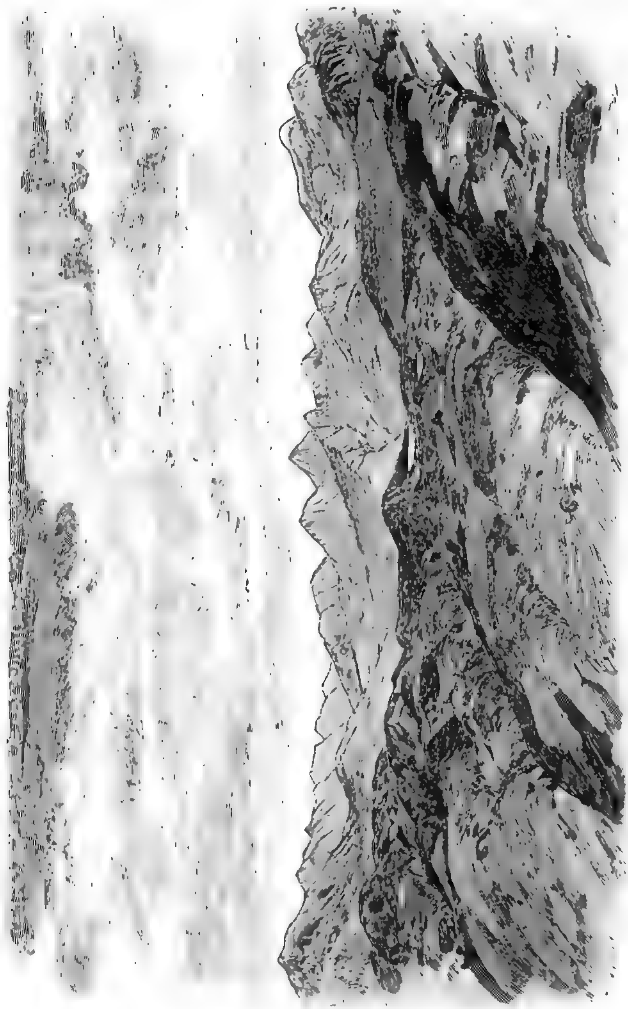

FIG. 59.—View across the West Highland plateau from the top of Ben Iadain, Morven. The highest point in the distance is Ben Nevis.

sweep its detritus into the glens and sea-lochs. The eastern heights, on the other hand, experience a less rainfall and consequently a diminished rate of erosion. There is no reason to doubt that the present preponderance of precipitation in the west has persisted for an enormous duration of time. The greater rainfall of to-day was probably represented in former ages by a greater snowfall, so that the glaciers would be larger in the western than in the eastern districts of the Highlands.

During its vast and protracted denudation, the framework of the country has been cut down to the very core. The erosion has necessarily been greatest along the drainage-lines; hence the excavation of valleys. But we have now to consider the general results on the rest of the country. In doing so we must remember that while the nature and grouping of the materials have varied from district to district, the erosion has been universal. We may therefore expect to find, amid the evidence of general denudation, great local diversities in the character of the results achieved. The more resisting rocks would naturally be left standing up as prominences, while those more easily degraded would be worn into hollows.

In the gradual evolution of the hills, full scope has been afforded for the modifications of form produced by variations in geological structure. The most important example of this influence is presented by the three great belts of country of which Scotland is composed, the north-easterly direction and individual characters of these belts being determined by the trend of the plications and dislocations, and by the distinctive variations in the nature and grouping of the rocks. The long north-east and south-west ridges of the Highlands are traceable to the same cause.

But besides influencing the general disposition of the high grounds, geological structure has played a great part in determining the individuality even of single ridges and hills. Though each eminence has been cut into its form by denudation, its actual outlines have been determined by the nature of

its rocks and the manner in which they have yielded to decay. Every distinct variety of rock has impressed its own characters upon the landscapes in which it plays a part. Hence amid the monotonous succession of ridge beyond ridge, and valley after valley, considerable diversity of detail has resulted from the varying composition and grouping of the rocks. It is to this cause that we must ascribe the great variety of Highland scenery. The mountains and glens, for instance, of Skye, of the Trossachs, and of the Cairn Gorm Mountains have all been carved out by erosion with the same sculpture-tools. Yet the results are in each case very different; because in each of the districts the rocks are distinct. In the north of Skye, the valleys wind among soft green terraced hills of igneous rocks, and almost recall some of the pastoral uplands of the southern counties. Around the Trossachs, the glens have been cut out of tough, gnarled schist, which is worn away unequally into knobs and bosses and steep craggy declivities. Among the Cairn Gorm Mountains, the savage cauldron-like corries and precipices have been carved out of granite—a rock which, from its usual decomposing character and its abundant vertical joints, combines in its decay a grandeur of lofty cliff with a flatness of mountain-top and a prevalence of "tors" and scree-slopes, such as no other Highland rock can boast.

These local peculiarities of scenery could be brought out only during a long process of sub-aërial waste. They must have reached their highest development just before the Ice Age began. For, as will be more fully dwelt upon in Chapter XI., the Highland glaciers and ice-sheets did much to break off the sharpness of the angles everywhere, and to give to the whole country a smoother and tamer aspect than it had worn before. Since that time, however, atmospheric disintegration has been ceaselessly busy upon the ice-moulded surface, and though the track of the ice still remains singularly fresh, it can be seen to be everywhere disappearing. In course of time, the rains and frosts will restore to the outlines of our

hills and mountains all the ruggedness which they possessed before they were swathed in the wintry folds of the ancient glaciers. In comparing and contrasting, therefore, the various forms of scenery to which the different geological formations give rise, it should not be forgotten that the distinctions between them are not so great as they were once, nor so marked as they will be again, when the ice-worn surfaces shall have faded away.

Perhaps the most interesting way of tracing the relation of the minor outlines of the landscape to the nature of the rocks, will be to take some of the more important rock-masses of the Highlands and connect their scenery with their geological character. For this purpose, it may be useful to adopt a chronological order and to begin with the oldest formations.

I have already dwelt upon the peculiarity of the landscapes of the Lewisian gneiss, which forms the Outer Hebrides and stretches as a broken belt along the western coast of Sutherland and Ross, and I have shown how extremely ancient is this type of topography, for it can be traced under the venerable Torridon sandstone. I would only repeat here that nothing can well be more impressive for its monotonous barrenness than an expanse of the grey, cold, bare gneiss, protruding from the heather in endless rounded crags and knolls, and dotted over with tarns and lochans, which, by their stillness, heighten the loneliness of the scene. Only at one locality on the mainland does it rise into an eminence that can rank with the more prominent hills of the younger rocks. In Ben Stack in Sutherlandshire it reaches a height of 2364 feet, and in its rugged declivities of crag and scar, shows its conspicuous veins of dark hornblendic rock and pink pegmatite. In the Island of Harris, however, it shoots out of the Atlantic in a group of extremely rugged and jagged mountains, which attain an elevation of 2662 feet. The lower slopes of these heights are intensely ice-worn, and consequently present the hummocky bossy character of the gneiss-belt in

Sutherland and Ross (Figs. 28, 60). But their upper parts, scarped by long ages of frost and storm, show the irregular craggy forms which the rock naturally assumes under ordinary sub-aërial disintegration.

The general character of the red Torridon sandstones, which lie upon the fundamental gneiss, and the great contrast in outline which they present to that rock, were referred to in Chapter VI. As this contrast is not only one of the most impressive in the Highlands to the observer of landscape, but also one of the most striking and instructive to the student who seeks to understand the origin of such diversities, I may be pardoned for again calling the reader's attention to it. The bleak, bare gneiss, with its monotonous undulations, tarns, and bogs, is surmounted by groups of cones, which, for individuality of form and independence of position, better deserve to be called mountains than most of the eminences to which that name is given in Scotland. These huge pyramids, rising to heights of between 2000 and 4000 feet, consist of dark red strata, often so little inclined that their edges can be traced by the eye in long level bars on the steeper hillsides and precipices, like lines of masonry. Here and there, the hand of time has rent them into deep rifts along their joints, whence screes descend into the plains, as stones are loosened from the shivered walls of an ancient battlement. Down their sides, which have in places the steepness of a bastion, vegetation finds but scanty room along the projecting ledges of the sandstone beds, where the heath and grass and wild-flowers cluster over the rock in straggling lines and tufts of green. And yet, though nearly as bare as the gneiss below them, these lofty mountains are far from presenting the same aspect of barrenness. The prevailing colour of their component strata gives them a warm red hue which, even at noon, contrasts strongly with the grey of the platform of older rock. But it is at the close of day that the contrast is seen at its height. For then, when the sun is dipping beneath the distant Hebrides, and the shadows of

night have already crept over the lower grounds, the gneiss, far as we can trace its corrugated outlines, is steeped in a cold blue tint that passes away in the distance into the haze of the evening, while the sandstone mountains, towering proudly out of the gathering twilight, catch on their giant sides the full flush of sunset. Their own warm hue is thus heightened by the mingling crimson and gold of the western sky, and their summits, wreathed perhaps with rosy mist, glow again, as if they were parts, not of the earth, but of the heaven above them. Watching their varying colours and the changes which the shifting light seems to work upon their strange forms, one might almost be tempted to believe that they

Canisp. Suilven. Coul More. Coul Beg. Stack Polly. Coygach Hills.

FIG. 60.—View of the Torridonian Mountains of Sutherland and Ross rising above the platform of Lewisian gneiss.

are not mountains at all, but pyramids and lines of battlement—the work, perhaps, of some primeval Titans, who once held sway in the north.

These huge isolated cones are among the most striking memorials of denudation anywhere to be seen in the British Islands. Quinaig, Canisp, Suilven, Coul More, and the hills of Coygach, Dundonald, Loch Maree, and Torridon, are merely detached patches of a formation, not less than 7000 or 8000 feet thick, which once spread over the north-west of Scotland (Figs. 30, 31, 60, and 61). The spaces between them were once occupied by the same sandstone; the horizontal stratification of one hill, indeed, is plainly continuous with that of the others, though deep and wide valleys or miles of low moorland may now lie between. While the valleys have been worn down through the sandstone, these strange pyramidal mountains, that form so singular a feature in the landscapes of the North-west Highlands, have been left standing, like lonely sea-stacks, as monuments of long ages of waste.

A singular feature in many of these sandstone pyramids affords another good illustration of the influence of geological structure in hill scenery. The Cambrian quartzite which was described in Chapter VI. as overlying the Torridon sandstone may be seen stealing up the slopes of the sandstone mountains, and even capping their summits. As these overlying patches are light grey or white in colour, the contrasting hues of the two rocks give rise to some of the most unexpected features in the landscapes. Under certain phases of the sky, when the light falls brightly on the tops of the dark red pyramids, the white quartzite looks like snow, and the long lines of white scree that strew the slopes might be taken for glaciers which have shrunk up the mountains almost to the limit of perpetual snow (Figs. 31 and 61).

Where a rock yields with considerable uniformity in all directions to the attacks of the weather, it is apt to assume dome-shaped or conical forms in the progress of denudation.

Sometimes this uniformity is attained by a general disintegra-

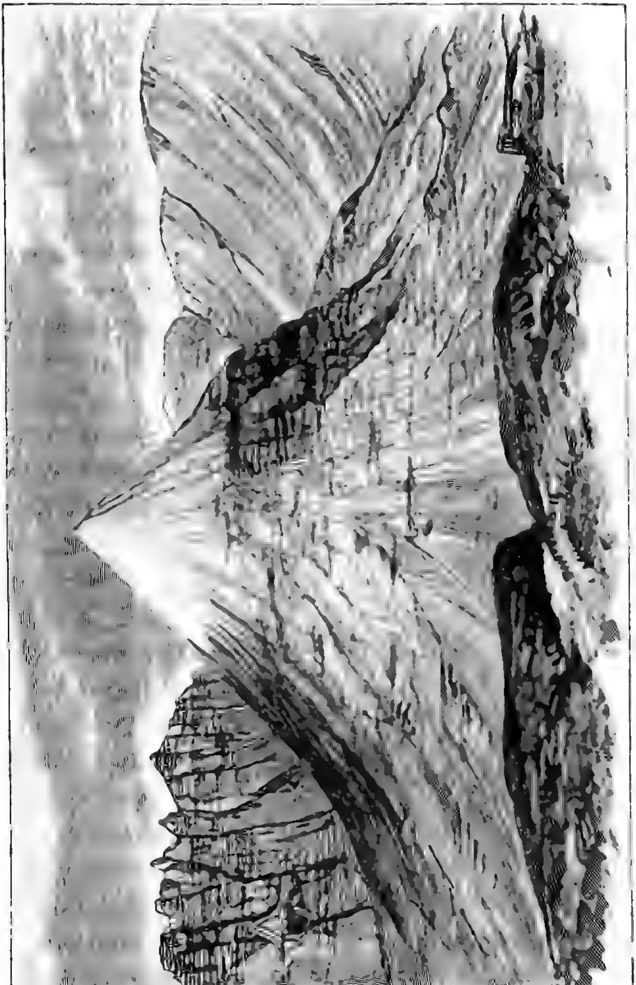

Fig. 61.—An Teallach, Dundonald, Ross-shire, showing the mural escarpments of the Torridon Sandstone and the conical weathering of its capping of white quartzite.

tion into fine detritus, under which the parent rock is gradually

buried, so that the resultant forms become smooth and featureless, and the hill assumes the shape of a rounded ridge or dome. In other cases, it is secured by the intersection of joints, whereby a rock, in itself hard and durable, is divided into angular blocks which, separated by the action of the elements, slide or roll down the declivities in sheets of scree. The upper part of a mountain disintegrating in this way is left exposed to continual waste, while the sides, as they shelve downwards, are better and better protected under the coating of rubbish. When the structure of the rock and the activity of the powers of waste are duly proportioned, the result is that the mountain, worn away above and shielded under its ruins below, grows more and more tapering, until it passes into a perfect cone. In many instances, the beginning of the formation of a cone may be detected on ridges which have been deeply trenched by valleys. The smaller isolated portions, attacked on all sides, have broken up under the influence of the weather. Layer after layer has been stripped from their sides, and the flat or rounded top has been narrowed until it has now become the apex of a cone. Admirable examples of this progress of sculpture are to be seen among the sandstone mountains of Western Ross-shire. Almost every stage may be detected, from the long ridge which has not yet been trenched, down to that which has been so deeply cut through that the separated portions have had time to be disintegrated into cones.

The thick zones of white quartzite, that form so notable a feature in Highland geology, supply many excellent illustrations of this kind of topography. Even in the thin quartzite cappings on the hills of Western Ross-shire, the tendency to take a conical form may be distinctly seen, as in the striking group of red sandstone pyramids of Dundonald, between Loch Maree and Little Loch Broom (Fig. 61). Shiehallien, in Perthshire, is a noble instance of a cone not yet freed from its parent ridge. Seen from the south-east, it appears as a long

rocky ridge, mounting slowly from the east and descending abruptly at its western end. But from the north-west, the ridge appears as a perfect cone, raising its gleaming peak of snowy quartzite to a height of 3547 feet, and throwing its rocky declivities far into the moors on either side (Fig. 62). The Ben Gloe hills and others towards the valley of the Dee prolong the same features into the heart of the Grampians. Again, far to the south-west, in the Island of Jura, the quartzite rises into the group of lofty cones known as the Paps of Jura, 2571 feet above the sea which almost washes their base (Fig. 57). The prevailing colour is grey, save here and there where a

FIG. 62.—Outline of Shiehallien (a mountain of quartzite).

mass glistens white, as if it were snow; and as the vegetation is exceedingly scanty, the character of the rock and its influence in the landscape can be seen to every advantage. The ascent of the mountains is impeded by the thick covering of loose angular rubbish, into which the quartzite weathers. But when once their summit is gained, the whole island with a wide panorama of sea and land beyond lies spread out as in a map. Nothing can exceed the distinctness with which the lines of stratification in the quartzite are traced on the cliffs and along the ridges. We can almost follow the line of each separate bed of rock as it winds across hill and crag, valley and tarn. Here and there on the white cliffs we detect the dark line of a

basalt dyke, pursuing its way towards the north-west, alike over precipitous mountain and deep glen, and bringing before us proof of the vast erosion of this region since older Tertiary time. Far below, along the northern shore of the deep inlet which almost cuts the island into two, we can see the line of caves worn of old by the breakers out of the same pale rock, and the mounds of shingle and marvellously fresh terraces of raised beach that now lie between them and the sea. There are few localities in the Western Highlands where greater scope is offered to the painter than among the glens and corries of Jura. The scenery possesses in itself much of the rugged dignity of the Highlands; the mountains have the advantage of rising directly from the sea, and thus among scenes of the most lonely and savage wildness there are glimpses of the wide Atlantic on the one side and of the blue mountains of Argyllshire on the other. The island has not been inundated by the flood of summer tourists; it remains one of the most primitive tracts of the Highlands, still unspoilt by the desecrating hand of the civilised Sassenach; and the artist, if he can obtain quarters, may there pursue his task undisturbed. He will find himself almost driven to enter upon a careful analysis of the elements of rocky scenery; for, amid the prevailing pale hues of the hills, his eye will be less apt to lose sight of the intricacies of form among the rich blendings of colour. And even if he should never make a picture out of his sketches, it will be strange if he does not find this enforced study of the structural character of rocks fraught with suggestiveness for future work.

With the bands of quartzite, that traverse the Highlands from south-west to north-east, limestone and dolomite are frequently associated, and the collocation of two such distinct kinds of rock produces another strong contrast of scenery. As the quartzite rises into ridges and mountainous masses on which it breaks up into rubbish that supplies but scanty nourishment for vegetation, it either remains bare, or is coated

with scraggy moor and bog. The calcareous rocks, however, yield a kindly soil, on which good grass and many flowering plants find a place. As has been already pointed out, tracts of such rocks are easily recognised in the Highlands, even at some distance, by the contrast between their bright verdure and the dun-coloured heath around them. From a hill-top we may trace the course of a limestone band for miles, as a belt of green, that winds from brown hillside into browner valley. The rock itself may protrude only in occasional knobs and hummocks. Where these occur on a grassy mound, they are usually found in some number, and, by one unacquainted with them, might naturally be taken for white mouldering tombstones standing in a long-neglected graveyard. Even across a swampy piece of moor, the limestone may sometimes be traceable by the line of pits or swallow-holes which, dissolved out of its outcrop by percolating water, allow the thick cover of peat to sink into them.

The schists and other crystalline rocks of the Scottish Highlands offer many illustrations of the connection between the nature of the material and the resulting form of the surface that has been carved out of it. The harder and more quartzose the rocks and the more regular their system of joints, the loftier and more rugged, as a rule, are the heights into which they rise. The gnarled and twisted mica-schists and fine-grained gneisses tower into some of the most conspicuous heights in the west of Inverness-shire. Perhaps the defile of Glen Shiel, with its encircling group of lofty naked hills, may be taken as one of the best examples of the more savage and rugged forms which these rocks assume (Fig. 58). Masses of bare rock piled upon each other give a corrugated outline to the steep acclivities which, deeply cleft by the gullies of the mountain-torrents and scooped into many a dark corry, sweep upward into an array of broken serrated ridges from which rise the peaks of Glenelg and Kintail. Less accessible but not less striking examples of the same type of scenery may be found

along the shores of Loch Hourn and Loch Nevis and among the glens that descend into these fjords. The height and the angular spiry forms of the ridges, the steep and deeply-rifted declivities, the ruggedness of the whole landscape, the dark hue of the bare crags, combined with the verdure of the lower slopes and shores, distinguish these two magnificent sea-lochs from the rest of the fjords of the west coast.

Amid such scenes as these, the influence of the stratification and joints of the gneiss and schist on the decomposition of the rocks can be traced by a geological eye far along the summits and slopes of the mountains. To this influence are due the parallel clefts which give rise to dark rifts down the steep scarps, and to deep angular notches on the crests of the ridges. To the same cause also, combined with the unequal waste that arises from varieties in the texture of the rocks, we may ascribe that gnarled craggy contour so characteristic of the gneissose hills of the Highlands, as well as the frequent tendency of the summits to assume spiry forms. Sometimes a whole mountain has been worn into a conical shape, but more frequently it is along the crests or at the ends of ridges that this outline occurs, and the reason seems to be that the gneiss and mica-schist are usually too various in texture and rate of decomposition to allow of the formation of a great cone like those of quartzite, while nevertheless uniform enough over lesser areas to give rise to small cones and spires along the summit of a mountain ridge.

Where the schistose rocks are of a softer and more uniform texture, they form large lumpy hills and long smooth slopes covered with heath or peat, through which the rock seldom protrudes, save here and there where a knob of harder consistency comes to the surface, or where a mountain torrent has cut a ravine down the hillside. Those wide tracts of the Highlands where the rocks are of this nature, possess a tame uniformity of outline which even their occasional great height hardly relieves. The traveller who crosses Ross-shire from

Loch Broom to Dingwall, through the dreary Dirie More, will be able to realise this oppressive monotony, and to contrast it with the scarped and precipitous mountains that rise on the south round Loch Fannich.

A better illustration of the effect of the softer schists in producing smooth-sloped hills can hardly be found than may be seen along the west side of the Firth of Clyde between the Kyles of Bute and the Gareloch. A band of clay-slate runs across the Island of Bute, skirts the firth by Innellan and Dunoon, crosses the mouth of Loch Long and the Gareloch, and strikes thence by Luss across Lochs Lomond, Ard, and Vennachar to beyond the Pass of Leny. It is easy to trace this strip of rock by the smooth undulating form of its hills, which remind us rather of the scenery of the Southern Uplands than of the Highlands. The slates, under the influence of the weather, crumble into small debris, over which a mantle of vegetation spreads, that gives the hills a smooth green aspect, and this tameness of surface is comparatively seldom interrupted by the occurrence of harder bands of sufficient thickness to form prominent external features. Behind this line of somewhat featureless upland lies a region of hard schistose grits and fine conglomerates (*ante*, p. 118). The contrast between the rough craggy outlines of these masses and the tame features of the clay-slate is a familiar part of the scenery of the Clyde. The hard tough character of the grits and their tendency to break up along their joints into large blocks, and to shelve off in sheets and faces of naked stone, produce gnarled, craggy, and bossy forms on the declivities and a notched and splintered sky-line along the crests. It is to such harder grit-bands that we owe the ruggedness of the mountains which sweep from the shores of Loch Fyne through Cowal, across the Holy Loch, Loch Goil, Argyll's Bowling Green, and Loch Long, into the heights of Ben Lomond, and thence by the Trossachs and Ben Ledi into the great range of Stuc-a-Chroin and Ben Vorlich. The craggy Highland character of these hills is heightened by

contrast with the softly undulating contour of the clay-slate belt in front of them, while in the Trossachs and along the shores of Loch Katrine and Loch Achray their ruggedness and gloom are softened by the fairy-like garniture of mountain-ash, oak, birch, and willow which lend such charm to that district of the Highlands.

Eruptive rocks take a less prominent place in Highland scenery than might have been anticipated. The most abundant and characteristic of them is granite, which covers such wide regions in Scotland. This rock presents considerable diversity of scenery, the several causes of which are not always easy to find. Sometimes, as in the Moor of Rannoch, granite extends over leagues of ground without rising into mountains; or, as seen from the top of Cairn Gorm, it swells into wide, tame, undulating uplands, roughened here and there by a mouldering knob or "tor"; or it mounts in huge craggy precipices far up into the mists, and encloses dark tarns like Loch Eunach and Loch Aven; or it sweeps into smooth domes like some of the Red Hills of Skye, or into groups of cones like Ben Loyal in Sutherland, or into a single stately cone like that of Goatfell in Arran. I have already remarked that some of these various and apparently incongruous forms may be found combined in the same district, nay, even in the same mountain. From the granite summits of Aberdeenshire and Inverness-shire the eye wanders over a wide, smooth, undulating table-land of hill-tops, and yet one or more of the flanks of each of these mountains may be a dizzy precipice 2000 feet in descent, with its rifts of winter snow hidden deep from the sun. Such is the character of the highest parts of the Grampians,

> "Around the grizzly cliffs which guard
> The infant rills of Highland Dee."

Certainly the widest region of the wildest scenery in Britain is comprised in the 100 square miles of savage mountain and

corry lying between Glen Feshie and Glen Quoich. It includes the summits of Ben Macdhui, Cairn Gorm, and other giants; the precipices of Loch Eunach and the Devil's Point, and the cauldron-like corries of Braeriach and Ben-na-Bhuird (see Figs. 12 and 40).

While the innumerable joints, both parallel and oblique to each other, which traverse granite enable rain and frost to split it up, the ultimate topographical forms into which the rock weathers depend greatly upon the angle of the surface exposed to

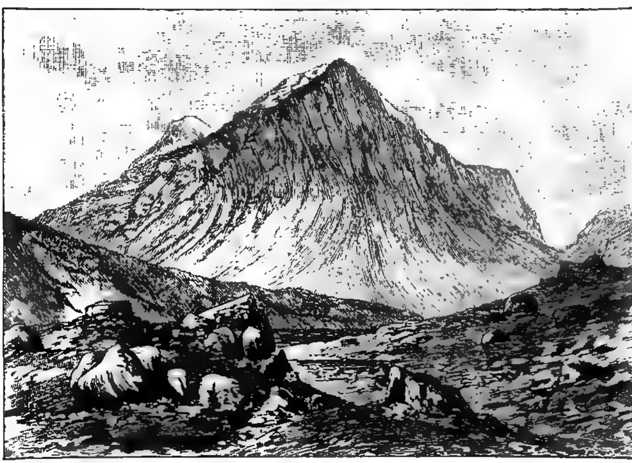

FIG. 63.—Buchaille-Etive (the Herdsman of Etive), from the east.

the attacks of the elements. On a horizontal or gently-inclined surface, the sub-aërial agents of decay act with diminished effect in splitting open the joints, after the upper layer of rock has broken up into angular rubbish. That layer, though always wasting away at the surface, is always renewed underneath by the progressive decay of the solid rock, but so slowly as practically to protect the rock below. But a vertical wall or steep face of granite may for a long while maintain its precipitousness. Slice after slice will be removed from it,

each of them being determined by joint-surfaces, and thus retaining their clean-cut character. The heaps of angular blocks that fall to the bottom of the precipice are further broken up by the weather, and ultimately washed away down to the low grounds. Hence the precipice shrinks backward into the mass of the mountain, as may be impressively seen on any of the corry-cliffs of the Aberdeenshire granite regions, such as the north front of Lochnagar (Figs. 12 and 54). To this unequal weathering, dependent in great measure upon the closeness and angle of the joints, I believe we should ascribe the singular extremes in the scenery of granite mountains, as well as the picturesque forms which are often assumed by "tors" and groups of granite boulders.

Hardly less conspicuous than the masses of granite are the bosses of gabbro which in Skye, Rum, and Mull tower into such conspicuous landmarks. The Cuillin Hills in Skye afford the most striking and best-known example of the peculiar contours assumed by this rock, and their contrast with the neighbouring and equally distinct Red Hills gives another and impressive lesson on the influence of geological structure upon outer form. To the west, the black spiry serrated peaks of the Cuillins, rising out of the green, terraced basalt-table-land, cast their shadows over the sea-lochs at their base, while eastwards a group of reddish or yellowish, smooth, blunted cones and rounded domes of granite likewise rises out of the sea. These two strikingly different rocks are both eruptive masses, of vastly younger date than the granite of the Highland mainland, for they are connected with the volcanic action to which the great Tertiary basaltic plateaux are to be traced. They were certainly not erupted at the surface, though, as already suggested, they may originally have been intruded in conical or *puy*-like forms. They were injected under and into the overlying basalts, and they consolidated under some depth of rock since removed. Their appearance at the surface is thus the result of prolonged denudation, in the progress of

which they have been sculptured into their present forms. The hard dark jointed gabbro has given rise to the black, crested and serrated ridges and peaks of the Cuillins, while the granitoid rocks have crumbled into cones, like Marsco, Glamich, and the other Red Hills.

Let us now consider the influence manifested in Highland scenery by those rocks which are disposed in parallel beds or strata. I have already had occasion to allude to the majestic examples of this influence in the red (Torridon) sandstone hills of Western Sutherland and Ross. Where stratified rocks have been greatly crumpled and dislocated, they lose much of their distinctive character, but where they remain flat or only gently inclined, they assume certain well-marked forms which present a great contrast to those of the crystalline rocks. The parallel lines of bedding stand out along the slopes and cliffs, while the vertical joints allow steep walls of rock to appear and to be cleft into deep notches or to weather into massive quadrangular buttresses and tall jointed columns. This union of vertical and horizontal lines imparts a strangely architectural aspect to hills formed out of stratified rocks, insomuch that the observer, as his eye wanders over the scenery, instinctively seeks to find, in the language of the architect, terms that shall be adequately descriptive of the topographical forms.

The level lines of cliff or steep bank, rising above gentle slopes and marking the edge or outcrop of harder beds, are known as "escarpments." Such lines of cliff may run for many miles across a country, winding into wide and deep bays and protruding into the plains as bold promontories, and reminding us in these features of a long indented coast-line. Or they may rise one above another into high terraced slopes, or tower into lofty pyramids. The numerous escarpments of the Secondary rocks, which stretch across England from the headlands of Yorkshire to those of Dorset, are typical features in English scenery. More conspicuous are the high plateaux of Sligo, Mayo, and Clare in the west of Ireland, where hori-

zontal beds of limestone lie piled one above another to a height of 2000 feet, and present ranges of magnificent escarpments and noble sea-cliffs towards the Atlantic. In Scotland, however, the stratified rocks have for the most part been so dislocated and disturbed as to prevent the formation of continuous escarpments, and this interesting form of rock-scenery is consequently almost entirely absent, except locally and on a small scale. The Torridon sandstone mountains of Western Sutherland and Ross-shire contain, perhaps, the most colossal escarpments in the country. The southern front of Leagach, for example, a mountain in Glen Torridon, exposes a vertical thickness of more than 3000 feet of almost horizontal beds of sandstone (Figs. 31, 60, 61). More impressive still are the huge escarpments and gloomy corries to the west of Loch Kishorn in the Applecross group of hills. The Old Red Sandstone within the Highland area forms some conspicuous heights, such as the two Ben Griams, the line of rounded hills above Golspie, and Morven in Caithness (Figs. 43, 44). But in these northern hills, the stratification does not greatly influence the external features. Beyond the southern margin of the Highlands, however, in the Braes of Doune, some of the conglomerate mountains present lofty terraced slopes towards the Highlands, along the sides of which the parallel bedding of the rock forms conspicuous lines (Fig. 46).

But the most extensive Scottish escarpments are displayed by the igneous rocks. Where lava has been piled up in successive nearly horizontal sheets, with occasional layers of tuff or other softer rock between them, it offers conditions peculiarly favourable for the formation of escarpments. The wide basalt-plateaux of the Inner Hebrides exhibit these conditions on a great scale. Unlike the eruptive rocks already referred to in this chapter, these youngest of the British lavas have been poured out at the surface, and have assumed the form of successive sheets, as in the terraced plateaux of Skye, Eigg, Canna, Muck, Mull, and Morven.

These detached areas may have formed originally a continuous plain of basalt that filled up the great depression now occupied by the sea to the west of the mainland of Inverness-shire. We have seen that, though dating back only to older Tertiary time, this volcanic platform has been so deeply trenched by denudation as to have been reduced to mere scattered fragments, that thousands of feet of basalt have been worn away from its surface, that deep and wide valleys have been carved out of it, and that so enormously has it been wasted as to have been entirely stripped off from wide tracts which it certainly once covered. In consequence of this stupendous denudation these lava-streams now play a far more

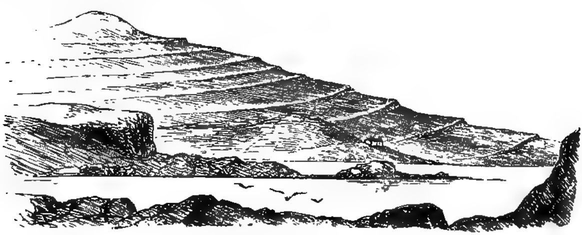

FIG. 64.—View of a portion of the basalt-plateau, Isle of Eigg.

conspicuous part in West Highland scenery than they originally did. When they were poured out they formed only a wide lava-field or succession of lava-fields across which the rivers from the neighbouring Highlands made their way to the Atlantic; and it is to the ceaseless operation of these rivers and their tributaries that we must mainly attribute the cutting down of the lava-plain into its present fragmentary condition. Though the basalt-plateaux have suffered so much from waste at the surface, they seem to have been but little affected by subsequent subterranean movements. An occasional fault elevates or depresses a portion of the plateaux for some hundreds of feet (Fig. 50), and it is possible that other parts have subsided and are now submerged beneath the sea. But the

horizontality or low inclination of the basalt, which remains so wonderfully persistent all through the Inner Hebrides, and the truncated ends of the successive sheets of lava, as revealed along mile after mile of magnificent sea-cliff, suggest that the basalt-fields, comparatively little affected by underground movements, have been reduced mainly as the result of prolonged denudation.

Piled over each other in nearly horizontal sequence, these sheets of rock attain in the north of Skye a thickness of at least 2000, and in Ben More, Mull, of more than 3000 feet. Owing to their variable destructibility, some bands, more especially the intrusive and frequently columnar sills, stand out as prominent dark ribs along the hillsides and the sea-precipices, while others, particularly the vesicular or amygdaloidal sheets, protrude less boldly and continuously or crumble away into slopes of debris. Hence the profile of a hill in these districts usually shows a succession of terraces, each of the harder beds standing out sharply against the sky, like one of the steps of a staircase. The decay of the rocks furnishes a rich brown loam, which supports a luxuriant growth of grass, so that the basalt districts are distinguished by their greenness even up to the tops of the hills. Almost every valley in the north of Skye has its ranges of escarpments of flat basalt-beds, with their flanking green slopes. Every sea-cliff is barred with the same horizontal belts of amorphous and columnar rock (Figs. 22 and 65). The flat tops of the hills, too, coincide with the surface of basalt-beds, as is conspicuously seen in M'Leod's Tables, two terraced heights in the north-west of Skye, that rise more than 1600 feet above the sea (Fig. 49). The basalt escarpments of Mull, and of the smaller islands to the west of it, continue southwards that association of dark brown crag and green slope so distinctive of the scenery of northern Skye (see Frontispiece). The most important range of basalt cliffs on the mainland is to be seen in Morven, where the terraced hills that slope upward from the Sound of Mull

end off eastward in a line of dark precipices looking north

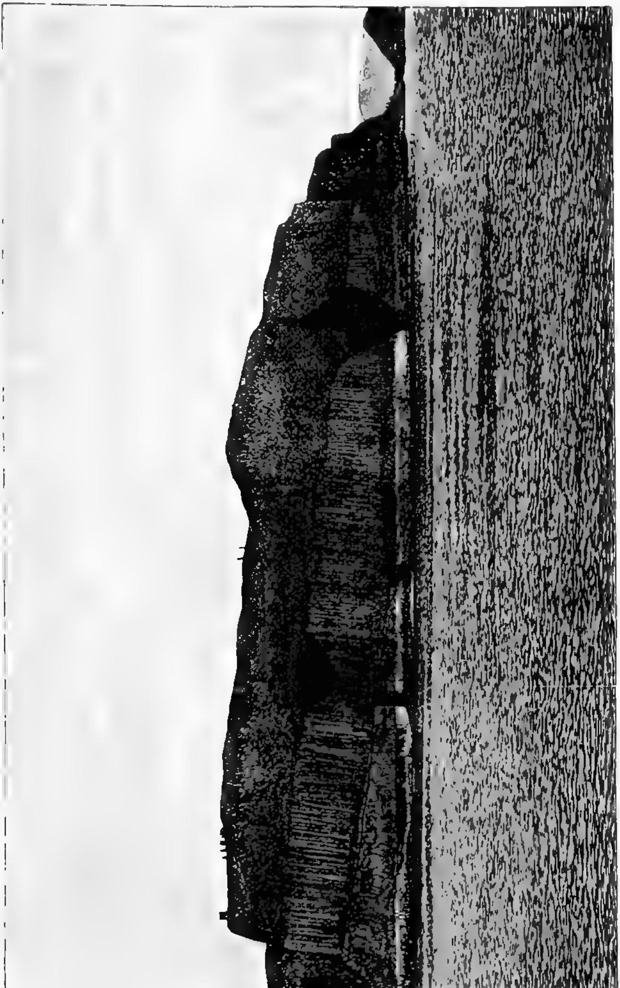

Fig. 65.—View of the south side of Staffa, showing the bedded and columnar structure of the basalt. The rock in which the cave to the left hand has been eroded is a volcanic tuff underlying the basalt; to the right is Fingal's Cave. These caverns bear witness to the enormous erosive power of the Atlantic breakers.

to Beinn Iadain (Fig. 50). The same geological structure,

accompanied by the same type of scenery, is prolonged in Antrim between Port Rush and Belfast, while far to the north it reappears in all its characteristic forms throughout the group of the Faroe Isles.

One who is familiar by report with the ruggedness and sterility of Highland scenery can hardly fail to be vividly impressed by the first sight he obtains of the singular landscapes of these basaltic districts. Instead of ruggedness, he sees with increasing wonder the long level lines of terrace that rise one above another, with strange regularity, sometimes twenty or thirty in number on a single slope, and wind along the hillsides till they are lost in the distance. Instead of sterility, he beholds grassy slopes, to which, for the exquisite brightness of their verdure, contrasting with the lines of brown crag and the dark blue sea, he would with difficulty find elsewhere a counterpart. I can recall the first impression of astonishment and delight which in boyhood such scenes printed indelibly on my memory. The penning of these lines brings also to my recollection many a subsequent hour of reverie spent among them. Often after a long day of geological activity among the Inner Hebrides have I paused on the homeward journey, to mark how the sinking sunlight, striking along those terraced and crag-crowned slopes, revealed with a vividness that was lost in the glare of noon, their union of dark projecting bars of rock and strips of lovely sward, to see how each little brook, that came tumbling down in white cascades from the uplands beyond, had cut for itself a notch in these bands of cliff, and to conjure up in imagination a succession of pictures of the same scene from the time when the basalt rolled out in successive streams of molten lava down to the legends of Fingal and Columba. In such musings, hours sped quickly past, until hill-top after hill-top would lose its flush of sunset, as if the dying day were slowly climbing the steps cut along the flanks of these terraced hills, and the chill shadows, struggling upward from dark and lonely glens, would creep up the same gigantic

staircase until the whole landscape melted into grey gloom, and the night began to fall.

But it is not only because they form lines of escarpment, or rise into hills, that the bedded rocks deserve the attention of the student of Highland scenery. Even where the stratified formations have given birth to no conspicuous topographical features, they sometimes contribute by no means an unimportant share to the local peculiarities of form and colour in the landscapes amidst which they lie. These rocks, where they here and there skirt the coast, present a strip of low ground which lies in strong contrast to the surface of the schists that rise from it. Thus along the shores of the Moray

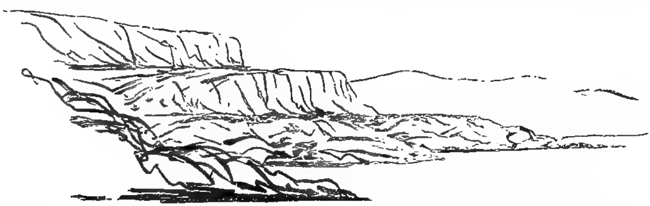

FIG. 66.—Rock-terraces marking ancient sea-levels, south coast of the Isle of Mull.

Firth, the brown rough mountains of the interior are fringed with a border of fertile ground, marking where the Old Red Sandstone, with its covering of drift, takes the place of the schists. Farther north, a similar contrast shows where the Jurassic sandstones and shales of Sutherland run as a narrow selvage along the coast, at the base of the line of rounded bare conglomerate hills which surmount them. On the west side of the island also, the Liassic and Oolitic strata, owing to the comparative richness of their soil and their low level, are sharply marked off from the more rugged and barren hills of schist, red sandstone, or granite, which surround them.

But, undoubtedly, the most marked contrast in form and colour along the eastern and western shores of the Highlands is made by the terraces of the raised beaches. These level platforms are usually carpeted with grass, or covered with culti-

vated fields, and run as belts of bright green along the bases of the dark rocky and heathery hills, in bays and such sheltered positions as have protected them. Where most fully developed at least five of these terraces may be counted. Thus in the Dornoch Firth, on the east coast, where they are remarkably well displayed, they occur at levels of about 15, 25, 50, 75, and 100 feet. These levels appear generally to rise towards the upper part of an estuary or strath, and the terraces merge into each other or into the alluvium of the valleys. Along all the firths from Inverness to Brora the raised beaches stretch mile after mile as prominent elements in the scenery.

The traveller up the west coast likewise encounters many examples of the same feature as he sails along. He will remark, among countless other examples, the singular green terrace that projects into the middle of Loch Linnhe at Corran Ferry, the flat moor to the north of Connal Ferry, the platform of verdant sward at Ardtornish Castle in the Sound of Mull, the grassy platforms, like lines of great fortifications, on each side of the entrance into Loch Carron, and the rock-shelves along the western base of the mountains of Applecross.

In some places the materials of the raised beaches have been too coarse or too infertile to yield a soil that would support vegetation, and they remain much as the last tide or storm left them. Of this type the most wonderful examples have been already referred to as stretching along the shores of Loch Tarbert on the west side of the Island of Jura. The barren quartzite shingle has there been left in successive platforms nearly destitute of vegetation. The traveller ascends with astonishment a series of shelves of this white coarse gravel, which rolls back with him as he climbs its slopes. He can hardly realise that it has lain there uncovered during the long lapse of time since the land was upraised.

[1] Some shingle ramparts which rise immediately above high-water mark and have been claimed as marking a recent rise of the land may be recent storm-beaches (p. 86, and Fig. 67*a*).

Throughout much of the west coast of Scotland the 50-feet strand-line is not one of deposit but of erosion, like the Seter or rock-shelves of Northern Norway. The land stood so long at that level that the sea had time to cut back a notch or platform in the solid rock. This rock-terrace forms a conspicuous feature in Loch Linnhe, particularly along the side of the limestone Island of Lismore. It is prominent also on the basalt-rocks of the south coast of Mull (Fig. 66). A fine example of it

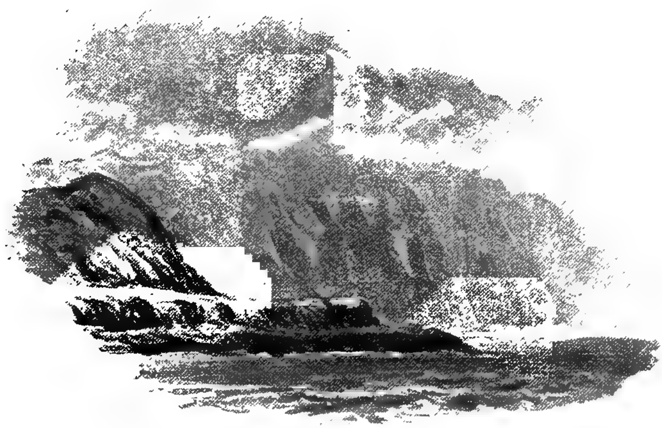

FIG. 67.—Rock-terraces of old sea-margins, east side of north end of Island of Jura.

may be seen at the south end of the Island of Rum, where it has been carved out of the Tertiary igneous rocks and the Torridon sandstone. On the east side of the Island of Jura the 50-feet and 100-feet terraces cut in the rock form conspicuous features for many miles (Fig. 67).

In landlocked inlets where the sea has little erosive power the platform is generally one of deposit. An excellent display of this feature may be seen along both sides of Loch Eil. The flat terrace has there formed a convenient surface for the new line of

railway from Banavie to Mallaig. Beyond the head of Loch Eil the same platform extends across to Loch Sheil. Hence at the time when this ancient beach was formed and when the land stood 50 feet lower than it does now, a continuous sea-strait wound through the mountains from the foot of the Great Glen by Lochs Eil and Sheil to Loch Moidart, thus making the extensive tracts of Ardnamurchan, Morven, Sunart, and Ardgower a large and much indented island.[1]

In concluding this chapter, I may refer to the influence of geological structure in determining the general character of the rocky foregrounds of Highland landscape. In larger measure than might be thought probable, the essential characters which mark the weathering of a rock in mountainous masses descend even into the details of form and colour among the crags and boulders of the lower grounds. Some rocks present great resistance to the disintegration of their component minerals, and yield to decay chiefly by the opening of their joints. Rocks of this nature split up into angular blocks, the forms and sizes of which are determined by the number, direction, and degree of closeness of their joints. They long retain their sharp edges and bare surfaces, though in the end lichens and mosses steal over them, and slowly provide a crust on which heath and ferns may grow. Other rocks, again, which weather by the decay of one or more of their constituents, and may crumble into mere sand, cannot retain the angularity which their joints would give them, and their blocks, becoming rounded at the edges, look like far-travelled boulders, though they may never have moved from the position into which they fell from their parent crag.

As illustrations of some of these kinds of individuality, let the geological traveller contrast the rocky foregrounds of the younger gneisses and mica-schists, of the Torridon sandstone, and of the eruptive rocks.

[1] J. S. Grant Wilson, *Summary of Progress of Geological Survey* for 1897, p. 146.

A mica-schist mountain may display a great corry scarped out of its side and crowned with a serrated line of peaks and clefts. On either side, the eye rests on dark beetling crags split open with parallel vertical rifts, as if they had been rent by an earthquake, and below these crags, piles of huge angular blocks strew the slopes and descend into the valley. In front, amid a heap of moraine-mounds that mark where a glacier once ended, we see these blocks scattered in profusion, and on the nearer ones we may note how distinctively the internal

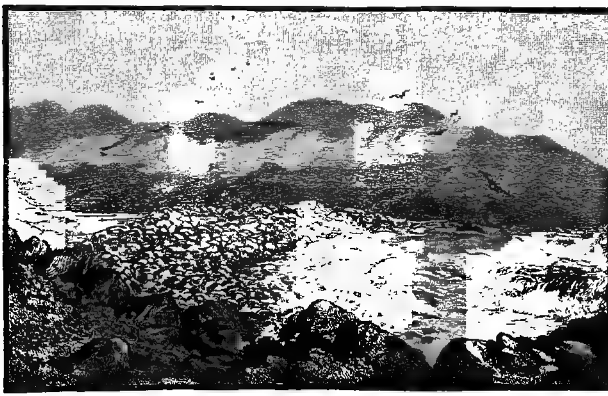

FIG. 67*a*.—Storm-beach ponding back a stream and forming a lake; west coast of Sutherland.

structure of the stone manifests itself in their outer forms—the twisted, crumpled lines of the foliation, the blending of white bands of quartz with streaks of darker minerals that vary the prevailing grey, brown, or pink hue of the stone, the silvery sheen of the white mica and the glance of the felspar or the garnets. And lastly, we shall not fail to observe how, while losing only very slowly their quadrangular forms, these blocks show in their component layers great differences in power of endurance, some bands projecting as hard ribs, others receding as deep hollows, yet that over all the hand of decay has passed,

yielding out of the mouldered stone sustenance first for crusts of grey and yellow lichen or of green velvet-like moss, and then for tufts of fern and foxglove mounting above the clustered wild-flowers, the tall purple heather, or the trailing briars, which in the end bury the boulder out of sight.

The Torridon sandstone, though it yields but slowly to internal disintegration, nevertheless is split along its lines of joint, which open into vertical rifts. It is the smooth bare walls of rock thus produced, that give the most distinctive characters alike to the mountains and to the crags of the lower grounds. Each cliff has its face, its projecting buttresses, its retreating recesses, and its narrow clefts defined by the joints. They are traceable, too, even on the detached blocks strewn below. A pile of such blocks reminds us of some gigantic quarrying operation. So slowly does the sandstone decay, and so little foothold does it supply for vegetation, that the sharp, flat, bare, unworn faces are retained by blocks that have evidently been resting many a long century alone on the moor. The dull red colour of the stone, too, gives it an additional distinction, which harmonises well with the sombre tints of the surrounding heath.

Granite in isolated crags and boulders varies in its power of resistance to decay as greatly as it does in mountain mass. But detached blocks allow some of the details of the weathering to be better examined. They show, for instance, how prone is the rock to disintegration by the decomposition of its felspar. Hence the angular masses, into which it splits by the opening of its joints, do not long retain their sharp edges (see Fig. 1). As they slide down the declivities and are attacked all over their surfaces by atmospheric disintegration, they crumble down into mere sand. This very rapidity of decomposition tends to keep them bare of vegetation, for the outer crust of rotten stone breaks up or is washed off before plants can take root upon it. A granite foreground consequently presents some peculiar and characteristic details. The rock

rises into bare bosses or tors, and these, by means of their vertical and horizontal joints, weather out into fantastic groups of rounded blocks, some of which may come eventually to be poised on mere points of their mass, and to form rocking stones. Everywhere the rounded forms of the granite meet the eye. The scattered blocks look so like worn far-carried boulders, that if we did not know their parent rock to be close at hand, we might suppose them to have journeyed from a long distance. Where the felspar is pink it may give a warm rosy hue to the stone, as in the beautifully-tinted pink granite of the Sound of Iona, but more usually the grey or white of that mineral remains with but little change on exposed faces. Hence, in its poverty of inherent colour, granite presents a strong contrast with many of the other rocks of the Highlands. Its ultimate tones in the foregrounds of a landscape are largely due to the crust of living or dead vegetation that spreads over its surface, contrasted with the natural hue of the naked weathered stone where this crust has been removed or has never been formed.

With all deference I would urge upon our landscape painters the propriety of studying these details of rock scenery more than they have yet done. It is not as a mere mass of light and shade, thrown into the foreground to give depth and distance to the picture, that a group of rocks and boulders is faithfully rendered on canvas. To the observant eye, there is as much individuality among the boulders as among our familiar trees. No painter would think of putting the foliage of a birch upon the stem of a Scotch fir; and surely it is not pedantry to protest against his placing square blocks of limestone in a district of granite, or rounded boulders among rocks which can only break up into angular masses. To such details, no conventional style of treatment can at all do justice. And the man who will truly paint these features must be content patiently and lovingly to study them.

CHAPTER X

THE HIGHLAND LAKES

One of the great charms of Highland landscape is the gleam of still water that so often gives the one element of repose in a scene of broken cliff and tumbled crag, of noisy cascade and driving cloud. No casual tourist can fail to notice what a wonderful variety of lakes he meets with in the course of any traverse he may take across the country. Among the higher mountains, there is the little tarn nestling in a dark sunless corry, and half encircled with grim snow-rifted crags. In the glen, there is the occasional broadening of the river into a lake that narrows again to let the stream rush down a rocky ravine. In the wider strath, there is the broad, still expanse of water, with its fringe of wood and its tree-covered islets. In the gneiss region of the north-west, there is the little lochan lying in its basin of bare rock, and surrounded with scores of others, all equally treeless and desolate.

While alive to all their charm and variety, the geologist experiences in sight of these lakes a peculiar interest, for he recognises in them one of the great problems of his science to which no completely satisfactory solution has yet been found. Many lakes indeed present no difficulty, but have their history plainly written on every surrounding lineament of the ground. Others, in spite of all that has been done to extract from them the secret of their origin, persistently refuse to tell it.

It must not be supposed, however, that there is anything

specially mysterious about the Scottish lakes. In considering their history, we are bound to remember that they are only a local exhibition of a feature that characterises the whole of the northern part of the northern hemisphere. They find their counterparts in Scandinavia and Finland on this side of the Atlantic, and in British North America on the other. They may be arranged in four classes, each of which has its own peculiar scenery, and has been formed in a different way: (1) Lakes of the plains; (2) Moraine-tarns; (3) Rock-tarns; (4) Glen-lakes. About the first two of these classes there is no difference of opinion, but much discussion has arisen as to the history of the last two.

1. The Lakes of the Plains, as their name denotes, do not properly belong to the Highlands, and I will therefore reserve

FIG. 68.—Section showing the structure of the basins of the Lakes of the Plains, lying in hollows of the superficial covering of drift.

the description of them until I come to the consideration of the Midland Valley, where they are so well developed (p. 404). But, for the sake of completeness of narrative, I may say here that these lakes generally lie in hollows of the covering of detritus left on the surface of country when the ice-sheets and icebergs retreated (Fig. 68). These superficial materials were thrown down very irregularly, and when water began once more to flow over the land, it gathered into the depressions and formed lakes.

2. Moraine-Tarns are small sheets of water ponded back by some of the last moraines shed by the retreating glaciers. They may be counted by hundreds in the Highlands, generally at the heads of glens or at the mouths of corries (Fig. 69; see also Figs. 12, 54, 92, 93). Probably the most southerly in the Highland region are those in the western part of the granite hills of Arran, of which the most picturesque is one which lies at the

foot of the corry on the seaward face of the northern end of Beinn Bhraec (spotted hill). The granite corries of Aberdeenshire furnish still more striking examples, such as those around Ben Macdhui, Braeriach, Cairn Gorm, Ben Aven, Ben a' Bhuird, and Lochnagar.

As a rule, lakes of this class are only to be seen among the high grounds. But in the north and west, where the glaciers came down to the sea, moraine-tarns are to be found at much lower levels. Loch Brora, for example, in the east of Sutherland, to which further allusion will be made in the next chapter, is only separated from the North Sea by a series of

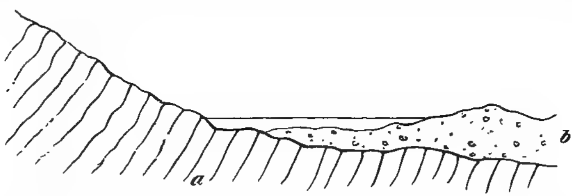

FIG. 69.—Section showing the structure of a Moraine Lake, where the water is ponded back by moraine mounds in a valley. *a*, Rock of the district. *b*, Moraine mounds.

moraine mounds and the raised beach which has been levelled out of them.

3. Rock-Tarns are small lakes lying in rock-basins on the sides of mountains, the summits of ridges, rocky plateaux, valleys or plains (Fig. 70). They have no necessary dependence upon lines of valley. On the contrary, they are scattered, as it were, broadcast over the districts in which they occur. They are by far the most abundant of all the lakes of the country. Dispersed over all parts of the Highlands, they are most numerous in the north-west, especially in the Outer Hebrides and in the west of Ross-shire and Sutherland. The surface of the Lewisian gneiss is so thickly sprinkled with them that many tracts consist almost as much of water as of land (Fig. 71). They almost invariably lie on strongly ice-worn platforms of rock. Their sides, and the rocky islets which diversify their

surface, have been powerfully glaciated. Their basins are not due directly to either fracture or subsidence, though they may lie on lines of fault. These basins have manifestly undergone great denudation, and have generally been recognised as essentially hollows produced by erosion. They have accordingly been assigned by many geologists to the gouging action of the sheets of land-ice by which the general glaciation of the country was effected.

One of the most familiar and striking examples of this class of lakes in the Highlands is undoubtedly Coruisk, in the Isle of Skye. Lying only a few hundred yards from the end of the Atlantic inlet, Loch Scavaig, and not many feet above the level of the sea, it is almost surrounded by an array of the blackest

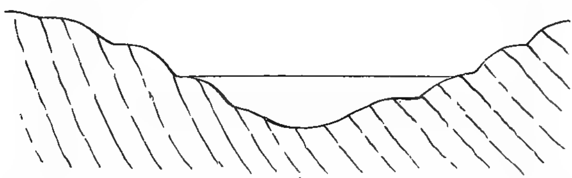

FIG. 70.—Section showing the structure of a Rock-Tarn.

and most jagged precipices in Britain. The rock (gabbro) of which these consist is of volcanic origin, and is endowed with singular toughness and durability. Along the crests and upper parts of the cliffs, it has been split by the weather, acting along its joints and dykes, until it presents a notched and splintered sky-line, to which there is elsewhere no equal within these islands. But lower down, where the ice that once filled the corry has been able to act upon its sides, this obdurate rock has been ground smooth, polished, and striated. Its very obduracy, which must have made the task of the glacier a more than usually laborious one, has enabled it to retain the impress of the ice-work with a freshness and perfection truly astonishing. Dome rises above dome, hummock beyond hummock, so smooth and shorn that it is difficult to realise that the ice has long since vanished from them. Polished

surfaces of rock form the lip of the basin, and their grooves and striæ, rising out of the dark sullen tarn, tell as plainly as words could do how the glacier that once filled the corry pressed its way up over that lip and out into the fjord beyond. Scores of huge blocks which, loosened by the winter frosts, fell on the surface of the ice and were carried onward, still rest where the ice left them—some perched on the brink of a crag, and thereby showing how gently, as the ice melted away from them, they settled down into their places. Impressive, therefore, as Coruisk is, considered only from the scenic point of view, it inspires still fuller wonder and admiration when the eye can both enjoy its picturesqueness and mark how marvellously it recalls some of the later aspects of the long Ice Age.

4. Glen-Lakes are those which occupy depressed portions of glens. They are not generally due to mere local heaping up of detritus, but are, for the most part, true rock-basins, often of great depth. It is around the question of the origin of this type that the discussion regarding the formation of lake-basins has chiefly centred. Glen-lakes include the larger sheets of water in the Highlands, and the great valley-lakes of mountainous regions generally, such as the larger lakes of the Alps. They have been regarded as due to special subsidence of their areas, to open fissures of the ground, to general depression of the central part of each mountain district from which they radiate, and to erosion by glacier-ice. That they are not open fissures, and cannot be explained by any general subsidence of a neighbouring region, is now generally admitted. That glaciers have occupied the glens where these lakes exist, and have worn down the rocks along the sides and bottom of the cavities, cannot be doubted; but whether the ice would be capable by itself of eroding hollows so deep as many of these lakes, is a question which has been answered with equal confidence affirmatively and negatively. On the other hand, to suppose that each of these hollows has been due to a special local subsidence would

involve a complex series of subterranean disturbances, for which some further evidence than the mere existence of the basins is required.

That some lakes, like many valleys, lie along lines of fault cannot be disputed. But as these valleys, though their trend has probably been determined by the dislocations, were nevertheless

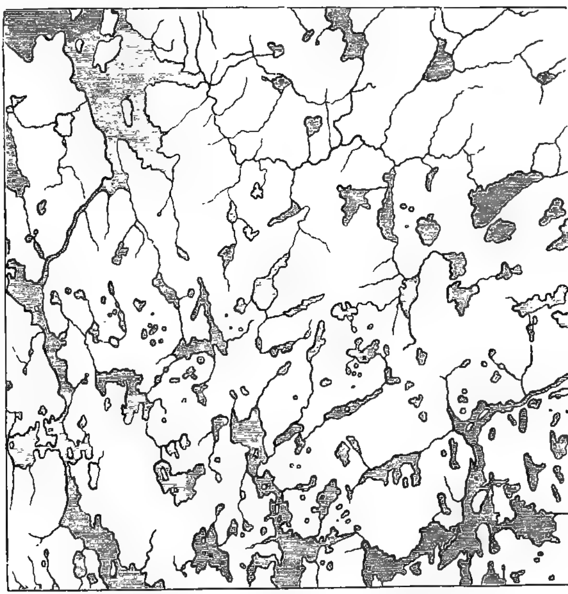

FIG. 71.—Part of the Island of Lewis, illustrating the remarkable abundance of rock-tarns in the districts of Archæan gneiss.

mainly due to erosion of the surface, so, following the same line of argument, we must regard the glen-lakes, even where they can be proved to have had their direction fixed by some line of fracture, as only indirectly due to underground structure, but mainly to denudation intensified along their basins. In the tracts of the Highlands which have been mapped in detail by the Geological Survey, and of which the geological structure is

now sufficiently known, it has been found that in the great majority of cases no connection can be traced between the position of the glen-lakes and lines of fault. The comparatively few good examples of that connection only show that faults have sometimes supplied lines of weakness along which lakes as well as valleys have been hollowed out. It has been definitely ascertained that some of the most important dislocations in the geological structure of the Highlands run across and not along the trend of some of the larger lakes. Thus, Loch Lomond and Loch Vennachar are crossed by the great boundary-fault, which is one of the most gigantic displacements in Britain. Loch Vennachar, indeed, is further traversed by at least two faults, one of which is the powerful line of fracture already alluded to as passing by Loch Tay and Glen Tilt into the heart of the Grampians. Yet the long axis of the lake runs across the trend of all these fractures, which at the most have only given rise to a slight deepening of the basin along their trend, where probably the broken and crushed rocks have been more easily denuded.[1]

Loch Lubnaig, Loch Earn, Loch Tay, and Loch Rannoch are also crossed by large faults. Loch Lubnaig consists of two basins, of which the lower and deeper actually lies on the upthrow side of the great fault.[2] In the case of Loch Tay, as has been already mentioned, the only influence which can be attributed to the fault is that of having directed the denuding forces in a north-easterly direction for a few miles, but the lake basin extends for miles on both sides of that deflection. While I am far from believing that we are in a position to dogmatise on this subject, to my own mind the view that glen-lakes have been hollowed out by denudation, and mainly by the action of land-ice, seems most in accord with the evidence, and to involve the smallest number of difficulties and contradictions.

The idea that glacial erosion has been concerned in the ex-

[1] Messrs. Peach and Horne, *Scottish Geographical Magazine*, vol. xvi. (1900), p. 234.
[2] *Op. cit.*

cavation of basins in the solid rock was first propounded by my old friend and colleague, Sir Andrew C. Ramsay. He contended that as these basins lie not in hollows of drift, but in naked rock, so they are not due to rents, or corrugations, or depressions of the earth's crust, but have been actually scooped out of the rocks; that, in short, they are true hollows of erosion, just as much as the river-valleys. Running water certainly could not have dug them out, nor the waves of the sea, nor rains, springs, or frosts. A glacier, however, as was pointed out in Chapter IV., is a powerful erosive agent, and in its operations is not bound by the same restraints as those which determine the action of running water. When a glacier is choked, as it were, by the narrowing of its valley, the ice actually rises. In such places, there is necessarily an enormous amount of pressure, the ice is broken into yawning crevasses, and the solid rocks suffer a proportionate abrasion. The increased thickness of the mass of ice at these points must augment the vertical pressure, and give rise to a greater scooping of the bed of the glacier. If this state of things last, a hollow or basin will be here ground out of the rock, and such a hollow once formed, there will always be a tendency to preserve it during the general glacial erosion of the bottom of the valley. On the retreat of the ice, this hollow, unless previously choked up with mud and stones, will be filled with water, and form a lake. It will be a true rock-basin, with ice-worn surfaces around its lip and over its sides and bottom.

There must obviously be a limit to this erosion, when, for instance, the pressure behind is no longer able to drive the ice out of the hollow, and when the lower portions remain embayed, and the upper parts are pushed over them. But that up to such a point ice is a powerful excavating agent can hardly be gainsaid. That the rock-basins in intensely glaciated districts, such as the Scottish Highlands, have themselves been filled with ice is quite certain. They exhibit along their margins, on their islets, and on their bottom, as far as it can be

examined, the same polished and striated rock-surfaces which are found universally throughout the kingdom. They are, indeed, as thoroughly moulded and striated from end to end as any part of the ground around them. This polishing and grooving of rock-surfaces has unquestionably been produced by the grinding action of sheets of solid ice. That the ice actually went down into the basins and grated along their bottom, seems proved beyond dispute by the grooves and striæ which can be traced slipping under the waters of a lake, rising and sinking again over the surfaces of the islets and submerged bosses of rock, and finally re-emerging with the same steady line of bearing from under the water at the farther end. We can thus prove that to some extent at least the rock-basins have certainly been eroded by ice. When one reflects on these facts and remembers that, as Ramsay insisted, they are not mere local phenomena, but are more specially to be seen all over the glaciated regions of the earth's surface; when one considers that like the glens, the glen-lakes are arranged with reference to the drainage of the country, that each of them has been the bed of a glacier, just as the valley above and below is the bed of a river, one cannot but feel, though the problem is not wholly solved, that rock-basins are inseparably interwoven with the glaciation of the regions in which they occur. It is inconceivable that the drainage-lines of the country were produced by underground movements, and it seems just as impossible to believe that the glen-lakes can have been produced by a series of rents and subsidences that occurred always in the valleys and were in each case neatly adjusted to the size and direction of the valley under which they took place.

Under any circumstances it is quite certain that the lakes must be of recent geological date. Any such basins belonging, for instance, to the time of the plication of the crystalline schists would have been filled up and effaced long ago. So rapid is the infilling by the torrents which sweep down detritus from the surrounding heights, that the present lakes are being

visibly diminished, and they cannot, therefore, be of high geological antiquity. If, indeed, the rate were measured at which these basins are being filled up, and if, further, we could ascertain how much sediment has already been deposited in them—an investigation which might not improbably be successfully accomplished in many instances—we might, as already remarked (p. 36), approximately arrive at a determination both of their antiquity and of the length of time which must elapse before they disappear.

It is worthy of remark that the glen-lakes are almost wholly confined to the western half of the Highlands, where they form the largest sheets of fresh water. Hardly any lakes save mountain-tarns are to be seen east of a line drawn from Inverness to Perth. West of that line, however, they abound both in the longitudinal and transverse valleys. The most remarkable line of them is that which fills up so much of the Great Glen. This singular straight depression, which cuts Scotland in two, has been already referred to as a great line of fracture in the earth's crust, probably dating back to an ancient geological period and subject to repeated movements along the same line.[1] Here, if anywhere, the believers in subterranean agency as the primary cause of rock-basins might look for

[1] Its very straightness is enough to suggest that the Great Glen owes its direction to a line of dislocation. I ascertained in the year 1864 that the effects of the fracture, or of one continued in the same line, can be seen along the western side of the Moray Firth where the Jurassic beds of Eathie and Shandwick are thrown down against the Old Red Sandstone. Hence the downthrow at this end of the line is to the east side. It seems to me that this line has been from a very early geological period, up to the present day, a line of weakness in the crust of the earth. The prolongation of the tongue of Old Red Sandstone up the valley of Loch Ness appears to show that the valley is older than that formation: the dislocation of the Eathie and Shandwick shales proves disturbance even after the Lias; and the agitation of the waters of Loch Ness, during great earthquakes in modern times, shows that even yet underground movements tend to reveal themselves along the same old line. Hence it may be reasonably conjectured that the fracture along the line of the Great Glen has been repeatedly modified during the subterranean changes of successive geological periods.

support to their views. They might insist that the sides of the glen are themselves the sides of the open fissure, worn down indeed by subsequent denudation, yet still gaping asunder as when they were first parted, and that the lakes lie in the deeper parts of this great chasm. But an examination of the valley will convince the observer that the amount of rock which can be shown to have been worn away from the surrounding ground would have far more than sufficed to fill up the cavities. Let him, for instance, stand on the ice-worn barrier of rock between Loch Ness and Loch Oich. He will see there that, even on the supposition of an open fissure, the deep concavity of the glen at this point must be due to denudation, for as the rocks can be traced across the bottom of the valley there is no room for a wide open fissure. The very arrangement of the rocks is enough to prove that the hollow has been worn out by the erosive agencies of nature; the upturned strata, vertical or highly-inclined, present their truncated ends to the sky, and can be followed bed after bed across the glen till they rise high into the hills on either side. Their bared ends, of course, were once prolonged upward: no fissure or fault could have exposed them; the lost parts can only have been removed by some agent which acted, not vertically like a fracture, but in a general sense horizontally, such as rains, rivers, frosts, ice, and the sea. In short, the glen at Fort-Augustus must be due mainly to denudation; the direction of the erosion being determined originally by the feature which the long line of crack made at the surface. And if this be the case at one part of the glen, where both its bottom and sides can be examined, the same structure can hardly fail to characterise the rest of the valley where it is filled by the lakes. The same evidence of extensive denudation, indeed, can be followed along the sides of the lakes. There cannot be any doubt that since the dislocation began, the hollow of the Great Glen has been enormously denuded. The material worn off its sides would find its way to the bottom, and first fill up the lakes, had these

existed. As the lakes are so deep, and still so little encroached upon by alluvium along their margins, they are certainly later than the formation of this long valley. It seems to me that this conclusion must be conceded even by those who most strenuously oppose the erosive power of ice.

If then the deep cavities of the Great Glen [1] are of later date than the scooping out of the valley itself, to what source must their origin be traced? There seem to be only two possible answers to this problem; the lochs must either be due to special fractures or subsidences after the formation of the valley in which they lie, or they have been dug out by ice. The question is thus narrowed to the same issue as that which every rock-enclosed lake proposes to the geologist. It may perhaps be impossible to prove that a valley, which had its course defined at first by a rent of the earth's crust, and which since then, up even to recent times, has been subjected to subterranean tremors, has not been rent open or depressed into deep lake-basins at a late geological period. But to affirm that it has been so is a mere assertion, for which some evidence from the ground itself, beyond the mere existence of the lakes, ought to be produced.

The Great Glen receives the drainage of a wide mountainous region on either side, and in old times a larger amount of ice probably flowed into it than into any other valley in Scotland. From the west came the large glaciers of Loch Eil, Loch Arkaig, Glen Moriston, and Glen Urquhart, from the east those of the Glens of Lochaber, and those which descended from the north-western flanks of the Monadhliath mountains. The sides of the valley show everywhere the flowing rounded outlines that mark the seaward march of the ice, and its rocky bottom, where visible, bears the same impress. That it has been ice-worn is thus rendered plain. Were there

[1] The deepest sounding in Loch Ness gives a depth of 129 fathoms opposite the Falls of Foyers; in Loch Oich, 23 fathoms; in Loch Lochy, a little below Letterfinlay, 76 fathoms.

no other examples of such ice-worn cavities in Scotland it might be too bold even to suggest that these lake-basins of the Great Glen may have been scooped out by ice. But when the same features can be seen in hundreds of other instances where no fracture or subsidence can be shown to exist, they may be reasonably treated with the other glaciated rock-basins of the country as hollows essentially due to glacial erosion.

Another example of a great dislocation along the line of which a series of lake-basins has been excavated has been already cited in the case of the fault which appears to extend from Strath Spey, by Lochs Ericht, Lydoch, and Awe, to the Sound of Jura. Loch Awe is one of the largest and noblest sheets of water in the country, and presents some problems of exceptional geological interest. The present outflow of the lake through the deep narrow gorge of the Pass of Brander is, comparatively speaking, recent. It has been opened across the lofty ridge that stretches from King's House through Ben Cruachan to the Sound of Jura. Though the ground has been carefully mapped by the Geological Survey, no evidence of a fault has been detected in that defile. I regard this as another example of a watershed cut through by streams which flow in opposite directions, aided doubtless both by the sea and by the stream of ice that came down from the opposite mountains and pressed through every available outlet to the ocean. But no one can ascend from Loch Crinan to Kilmartin, and thence up the terraced valley to Loch Awe, without being convinced that this must have been the old outlet of the great valley of that loch. The drainage from the cluster of long deep glens at the head of the lake descended into the main valley, and went out to sea in the Sound of Jura. The excavation of the long lake-basin, and the cutting through of the watershed by the Pass of Brander, are late events, both probably dating from the Glacial Period, while the origin of the main valley of Loch Awe carries us back infinitely far into the past. It is owing to this erosion of the valley and to the

cutting through of the Brander Pass that the water now flows into Loch Etive instead of the Sound of Jura or Loch Gilp. The geologist who ascends the valley from Kilmartin may well marvel when, standing at last on an ice-worn barrier of schist, he sees stretched out for miles before him the wooded shores of Loch Awe. He can there observe that the lake is dammed back by hard rock, that this rocky barrier has been smoothed, polished, and striated, and that the parallelism of the striation with the length of the valley and of the lake proves that a mass of ice once filled up the present basin of the lake, ascended over the rocky barrier, and passed down the valley towards Kilmartin. All along the sides of the loch, and on its rocky islets, similar traces may be seen of the steady southward march of the ice. The rocks are worn into smooth mammillated outlines, and covered with ruts and grooves that trend with the length of the valley. It is, in short, a rock-basin of which all that can be seen is ice-worn; and if further proof of the old glaciers were needed, it would be found in the heaps of moraine rubbish piled along the side of the valley.

The glen-lakes that lie in transverse are more numerous than those in longitudinal valleys, probably for the same reason that the transverse valleys exceed the others in number. They are likewise more picturesque, for as they run across the strike they traverse a greater variety of rocks, and these present their truncated ends along both declivities. As instances of this greater abruptness and variety of form, I may cite Lochs Lomond, Katrine, and Lubnaig in the Southern Highlands, and Lochs Morar, Maree, Assynt, and More in the west and north.

It is obvious that some lakes, like some valleys, are, strictly speaking, neither longitudinal nor transverse, as may be seen in Lochs Earn, Rannoch, Garry, Clunie, and Quoich. Lakes of this kind have doubtless had their trend determined in the same way as the valleys which cannot correctly be assigned to either of the two main systems, but which in their independence point to the drainage having originally taken a course that was

not influenced by at least the dominant geological structure now visible at the surface. That there should be lakes which take the same lines seems to furnish an additional piece of evidence in favour of connecting these basins with the valleys, as being essentially due to erosion along lines of drainage.

The great depth of some Scottish lakes has long been known. Loch Ness, of which the soundings are given on p. 257, was formerly considered to be the deepest; but soundings by Mr. J. Y. Buchanan in Loch Morar, the great transverse glen-lake of Arisaig, repeated and confirmed by Sir John Murray, have made known a far greater profundity than was ever before obtained. The surface of this lake is only about 30 feet above the sea, but the bottom descends to a depth of no less than 180 fathoms or 1080 feet. The sea-bottom immediately outside is nowhere nearly so deep as this extraordinary depression. The greatest depth recorded on the Admiralty charts of this part of the Scottish seas is one of 139 fathoms between the islands of Rum and Skye. But, so far as I can ascertain, not until we get westwards beyond the platform of the British Islands and begin to descend into the great basin of the Atlantic Ocean is a depth of 170 fathoms reached. Loch Morar appears to be the deepest known hollow on any part of the European plateau, except the submarine valley which skirts the southern part of Scandinavia (see Fig. 72).

A systematic investigation of the fresh-water lakes of Scotland has recently been undertaken by Sir John Murray and Mr. F. P. Pullar, and the first part of their researches, having reference to the lakes of the Trossachs and Callander district, has been published.[1] They have found that Loch Katrine, the surface of which lies 364 feet above sea-level, has a maximum depth of 495 feet; Loch Vennachar, lying 270 feet above sea-level, reaches a depth of 111 feet; Loch Lubnaig, 405 feet above sea-level, descends to a depth of 146 feet; Loch Rannoch, the surface of which is 667 feet above the sea,

[1] *Scottish Geographical Magazine*, vol. xvi. (1900), p. 193.

has a maximum depth of 70 fathoms or 420 feet;[1] Loch Tummel, 453 feet above the sea, reaches a depth of 124 feet, while Loch Tay, the largest of the Perthshire lakes, descends to a depth of 510 feet, or 164 feet below sea-level, the surface of the water being 346 feet above that level. Loch Earn has an extreme depth of 288 feet, its surface being 306 feet above sea-level.

The remarkable association of ravines with open meadow-like expansions of the valley above them has been already referred to (pp. 175, 198). It is noticeable that in not a few instances the expansion is occupied by a glen-lake. Many instances might be cited, such as the defile of the Trossachs with Loch Katrine above it, and the Pass of Leny, with Loch Lubnaig.

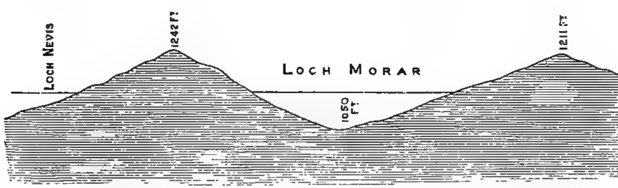

FIG. 72.—Section across Loch Morar, on the same scale (one inch to a mile) for breadth and depth.

The ravine or gorge will generally be found to have been eroded out of some tract of harder rock that has acted as a barrier below the lake. Thus, the zone of hard, massive grits and conglomerates in Ben Vorlich, the Trossachs, Ben Aan, and Ben Ledi has doubtless offered much greater resistance to erosion than the softer schists lying to the westward; so that while the latter were scooped out into the basin of Loch Katrine, the former rose as a great mountain barrier, only cut through by narrow valleys. Hence this feature in topography furnishes another piece of evidence in favour of the origin of such lakes by erosion rather than by underground movement. But in their case, the erosion has been carried by

[1] The soundings of Lochs Rannoch, Tummel, Tay, and Earn were taken some years ago by Mr. J. S. Grant-Wilson. *Op. cit.* vol. iv. (1888), p. 251.

glacier-ice far below the level at which the original stream acted. The softer nature of the rock which allowed the stream to widen its valley above the gorge would enable the ice to deepen it. As already suggested, many of the flat alluvial plains above gorges in the Highlands were probably at one time glen-lakes which have been gradually filled up. The process of infilling may sometimes be watched in its successive stages where a group of streams, liable to heavy spates and carrying large quantities of detritus, descend into one or more lakes. Good illustrations may be studied in the east of Ross-shire. Thus the River Bran has cut down the barrier at the lower end of Loch Coulin and lowered the level of the lake, so as to separate this sheet of water from Loch Achanalt, with which it was once connected. On the other hand, at the upper end of Loch Coulin the river has silted up the lake and spread out a great alluvial plain which stretches for some miles to the west. Another similar plain surrounds the head of Loch Luichart, formed of sediment principally brought down by the Grudie Water. At the head of Loch Garve a wide plain of alluvium has been formed by the Black Water, which is fast filling up that lake. The stream, by cutting out the gorge in which the Falls of Rogie are situated, has considerably lowered the level and diminished the area of Loch Garve. The successive shores of this sheet of water as it was lowered are marked by beach deposits which reach down to the top of the gorge.[1]

Large as is the number of still existing lakes in the Highlands, it is a mere fraction of the number that once existed. Everywhere we see them being filled up by the sand and mud poured into them by their tributary streams. The shallow basins, of course, disappear first; those that are deep and have steep sides last longer, and except at the upper end, where the main stream enters, may show little sign of diminu-

[1] Mr. B. N. Peach in *Summary of Progress of the Geological Survey* for 1898, p. 186.

tion. But they too are natural filters that receive the muddy water from the surrounding hillsides, and discharge it clear and bright at their lower ends. Every spate, therefore, helps to displace the water of the lake by an equivalent amount of sediment deposited on the bottom. Slowly but certainly each lake is diminishing in volume, and unless some new series of geological revolutions should begin, the result of the present operations of nature must inevitably be to convert every Highland lake into an alluvial plain.

CHAPTER XI

THE ANCIENT ICE-SHEETS AND GLACIERS OF THE HIGHLANDS

In the fourth chapter a brief outline was given of the effects produced on the surface of the land by the movement of sheets of ice across it. I propose to describe here the traces of the march of the ancient glaciers which have so profoundly affected the scenery of Scotland, and notably of the Highlands. It is now well ascertained that during a comparatively recent geological period, the climate of the northern hemisphere was much colder than at present, and that in the British Islands, as well as in other countries where glaciers are now unknown, the land was enveloped in snow and ice. This part of the geological record is known as the Ice Age or Glacial Period.

In following the track of the Scottish glaciers and ice-sheets, and noting how much they have modified the contours of the country, it must be borne in mind that the present great leading features of mountain and valley had been fixed before the snow and ice spread over them. The minor outlines of the surface, however, were in some respects unlike those which we now see. There was doubtless far more angularity and ruggedness about the aspect of those ancient landscapes. For so prolonged a series of ages had the land been continuously exposed to atmospheric disintegration that a covering of rotted rock stretched over much of its surface, through which the harder and more durable prominences projected. The ice which eventually settled down upon the country did

much to remove these asperities of contour, to scrape off the ancient mantle of decayed material, and thus to smooth the general surface. But though the ice abraded the valleys, it did not make them. Keeping in recollection, therefore, that hill and valley were grouped into their present arrangement before the ice began to settle down upon them, let us look for a little at the evidence from which this strange chapter in the country's history is deciphered.

FIG. 73.—Ice-worn rocks, Rispond, Sutherland.

The surface of Scotland, like that of Ireland and of the northern half of England, as well as the whole of Scandinavia and Northern Europe, is distinguished from more southern countries by a peculiar contour, visible almost everywhere, irrespective of the nature of the rock (Fig. 73). This contour consists in a rounding and smoothing of the hills and valleys into long flowing outlines. What were no doubt once prominent crags have been ground down into undulating or pillow-shaped knolls, while deep hollows and gentler depres-

sions have been worn in the solid rock. It may seem paradoxical to speak of the well-known rugged Highland mountains as showing traces of a general smoothing of their surface. But such is really the case. There may be places, indeed, where from height, or steepness, or some other cause, the smooth surface was never communicated; and there is everywhere a constantly progressing destruction of that peculiar outline: the rains, springs, and frosts are reasserting their sway, and carving anew upon the country its ancient ruggedness. Nevertheless, to an eye which has learnt to distinguish the characteristic flowing lines, there are not many landscapes in the kingdom where they cannot be traced. Even in the wildest Highland scenery, where the casual tourist may see nothing but thunder-riven crags and precipices, and glens blocked up with their ruins—

> "Precipitous black, jagged rocks,
> For ever shattered and the same for ever,"—

an eye trained to observe it can detect the same universal smoothing and moulding. Nay, it is precisely amid such scenes that the geologist is most vividly impressed with the fact that the general surface of the country has been ground down. He there sees the natural outlines which the rocks assume when left to the ordinary attacks of the elements. He can note that the smooth undulating outlines have here and there been replaced by craggy precipices and scars, which are raw and fresh, where the last winter's frosts have let loose masses of rock into the valleys below. He may trace how, in this way, the hand of nature is once more roughening the landscape, restoring to the hard rocks their cliffs and ravines, and to each knoll and crag a renewal of its former angularity. Yet his eye rests continually upon little bosses of rock, or even upon whole hillsides where, owing to a covering of drift or soil, or to the enduring nature of the material, the change has gone on but slowly, and where he can still view the uneffaced

traces of that wonderful process by which the surface of the country from Cape Wrath to the Solway has been worn and smoothed.

This widespread abrasion can be seen on hill and crag, hummock and knoll, from the shoulders of the mountains down to below the level of the sea. It is traceable upon all the little dimples and prominences on a freshly exposed surface of rock. The hardest materials usually show it best, and when the soil and superficial detritus are stripped from them, their faces may often be seen to be as smoothly dressed as if they had been cut in a mason's yard, and were meant to form part of the polished ashlar-work of a great building.

Further, not only have the rock-surfaces been thus planed down, they have been covered with long more or less parallel ruts and striæ, varying in depth and width from mere streaks, such as might be scratched with a grain of sand, up to grooves like those worn in old pavements by the cart-wheels of successive generations. The fine scratches may be seen descending into the hollows and mounting over the prominences of a rock, keeping all the while their general direction, with about as much regularity and persistence as they do over the most even surface. These markings have obviously been produced by some agent that moved across the face of the country, grinding down, scratching, and grooving the rocks as it passed along. No violent or transient debacle will account for them. They can only have been made in a quiet, deliberate way, by some force that paid little or no regard to the minor inequalities of the ground, but passed on with a steady persistent march, pressing grains of sand, pebbles, and even large blocks of stone upon the rocks below, so as to leave there at last a smooth polished surface, marked by striation of varying coarseness, according to the nature of the rude polishing paste of detritus.

When the ruts and scratches are examined, district by district, they are found to reveal a remarkable arrangement.

They have not been distributed at random, but regarded with reference to the topography of each region, are found to radiate from the main mountain masses outwards to the sea (see Map of the Glaciation of Scotland in Plate IV.). Down all the western fjords, they may be traced along the wavy undulating bosses of polished rock, until they pass beneath the waters of the Atlantic. Along the Pentland Firth, they may be seen in like manner descending from the high grounds of Sutherland northwards to the coast-line. On the eastern side of the island, the same seaward trend of the ruts and striæ on the rock is traceable. The general direction of these markings in the Perthshire and Stirlingshire Highlands is south-eastwards into the valleys of the Forth and Tay, whence it turns to the east into the basin of the North Sea. In the maritime parts of the counties of Forfar, Kincardine, and Aberdeen it bends round towards the north-east. The movements of the ice which these variations in the trend of the striæ indicate are alluded to on p. 278. Into the long depression of the Great Glen, the striæ come down from the high mountainous tracts on either side, and turn into the line of the valley, so as to run out into the Moray Firth on the north and into the Linnhe Loch on the south. In the glens that open upon the estuary of the Clyde, the rocks are striated along the line of each valley, the groovings passing up inland into the high grounds of the interior, and striking outwards beneath the sea. These markings prove that the mass of ice moved southwards from Loch Lomond, crossed the Clyde, passed over the hills of Renfrewshire, and crept down into the heart of Ayrshire, where it united with the ice that was streaming northward from the Southern Uplands. The very islands in the Firth of Clyde are striated in the same way. Bute, for instance, is a notable example, for the striæ, after coming down the glens of Cowal and passing beneath the Kyles, reappear on the Bute shores, actually mount the slopes of the island, so as to go right across it at a height of more

than 500 feet, and descend upon the firth on the south-west side (Fig. 74).

Again, we can sometimes trace the glacial groovings out of one glen or sea-loch over a high watershed into another valley. Thus from Loch Lomond, these strange almost indelible markings can be seen striking through the short cross valley at Tarbet and descending upon Loch Long at Arrochar. From the latter loch, again, they may be followed over the watershed which separates that fjord from the Gareloch, and thence down the latter valley into the Clyde.[1] In Loch Fyne also, continuing in the line of the upper part of that valley,

FIG. 74.—Ice-worn rocks near summit of Barone Hill, Bute.

they are not deflected when this loch makes a bend south of Ardrishaig, but actually ascend the hills above Tarbert, and cross heights of 800 feet into the Sound of Jura.[2]

There is no great sea-loch or glen on the west coast where these features may not be seen to a greater or less extent. From the remote fjords of Sutherland, down to the inlets of Cantyre, every valley that opens into the sea will be found to tell the same story of abrasion and striation. As an example, at once easily visited and eminently characteristic, I may refer to the valley of Glendarual, which, descending from the mountains of Argyllshire, opens into the inlet of Loch Riden and thence into the Kyles of Bute. If the observer will take

[1] C. Maclaren, *Edin. New. Phil. Jour.* vol. xl.

[2] T. F. Jamieson, *Quart. Journ. Geol. Soc.* vol. xviii. p. 177.

boat and row gently along the rocky shore, and among the numerous islets of the comparatively short estuary of Loch Riden, he will be amazed at the freshness with which the smoothed and striated rock-surfaces have been preserved. Steering his way between the islets and headlands, he will notice that on looking towards the head of the loch, his eye catches the rough blunt faces of the different crags and knolls; that, as he passes them, their sides, parallel in a general way with the sides of the loch, are well polished and striated, and that their upper ends, or those which face up the loch, are all worn down and smoothed off. He could not desire a more instructive lesson as to the nature of that smoothing process to which the surface of the country at large has been exposed. The striæ running parallel to the loch, the blunted and worn aspect of those parts of the crags and hummocks of rock that look up the valley, and the comparatively fresh and rough faces of those that look towards the open sea, indicate, as plainly as words can do, that the agent which smoothed and striated the sides of Loch Riden must have moved downwards along the length of the valley from the high grounds of the interior. Nor is this all. An ascent of the valley of Glendarual, above the head of the sea-loch, will show that the agent which produced the striation must have filled up the glen to the brim, and actually overflowed it. For the long parallel markings on the rocks can be followed as they slant over the west side of the valley and pass across the hills of Cowal some 1300 feet in height into Loch Fyne. The ground between that loch and the Glendarual valley has been worn down into many hollows which, with the striation, trend away to the south-west.

It was at one time believed that these polished and striated surfaces of rock were produced by icebergs, when the land stood at a lower level than now. But this notion has now been universally abandoned. The striæ do not merely run along the top or side of a hill, as they might be supposed to do if grating icebergs had made them. They run up and over

the ridges and hills, accommodating themselves to all the little inequalities of the surface over which they pass. This could never have been done by a rigid mass of ice moving horizontally like a berg or floe, with no determinate motion of its own, but driven by ocean-currents and winds. On the contrary, it points to an agent endowed with such plasticity as to be able to mould itself upon the irregularities of its rocky bed and to rise or fall as the nature of the ground required. And this agent, as shown by the divergence of the striæ, must have moved outwards and downwards from the chief mountain masses, such as the Grampians and the chain of heights from Loch Eribol to the Sound of Mull. It must have filled up wide and deep valleys, pressing everywhere steadily and mightily upon the rocks, disregarding the minor features of the surface of the country, passing over hills many hundred feet high as if they were mere boulders, and continuing its operations over so long a period as finally to leave the country smoothed and polished, or, as it were, moulded into a flowing undulating contour.

To fulfil these conditions the only agent known in nature is land-ice. As was stated in Chapter IV., the polished and striated rocks find their exact counterparts along the course of every modern glacier. There is hardly a Highland glen, nay, strange as it may sound, there are not many hillsides, even of the Lowlands, which do not remind one of the *roches moutonnées* or ice-worn knolls of the Alps. The moulded outlines are the same, the striæ are the same, and the parallelism of the striation with the direction of the long valleys is alike the same, in Scotland and in Switzerland. In comparing the rock-markings of the two countries, we are driven to admit, that as in one case we see these markings to be manifestly the work of moving glacier-ice which is still there producing them, so, in the other instance, the precisely similar effects must be due to the same cause, although the Scottish glaciers have long since disappeared.

In the year 1840 Agassiz, fresh from a study of the Swiss

glaciers, came to Scotland and announced this conclusion as the result of his examination of the Highland glens. But British geologists tried every other expedient for somewhere about a quarter of a century before they began generally to adopt the views of the great Swiss glacialist. Their difficulty lay not in the admission of the existence of glaciers in Scotland, for admirable descriptions of glacier-moraines and striæ in Skye, Forfarshire, and Argyllshire, were published by J. D. Forbes, Lyell, and C. Maclaren. But if the universal striation were everywhere taken as evidence of the existence of land-ice, it was plain that Scotland must not merely have been the seat of local glaciers, as Switzerland and Norway are at the present day, but must have been actually sealed in ice from mountain-top to sea-shore, like Northern Greenland. This was a supposition too violent for ready credence, and hence geologists, having at that time no scruple in invoking any conceivable amount of subterranean disturbance for which they had little or no evidence, preferred to adopt a belief in a general submergence, not of Britain only, but of much of Europe, including great part of the lowlands of Switzerland. Dismissing the notion of sheets of land-ice, they adopted in its stead and stoutly upheld the doctrine of the abrasion of the land by floating ice.

But the iceberg hypothesis has long been abandoned. Geologists were reluctantly, and against all their previous speculations, driven to confess that, after all, Scotland, with the greater part of England and probably the whole of Ireland, must have been swathed in one vast wintry mantle of snow and ice. This thick icy envelope, ceaselessly pressing down towards the sea, must have had a constant grinding movement far grander in its geological results than that of any mere valley-glacier. A glacier wears down only the sides and bottom of the valley in which it flows; but a great ice-sheet, covering the length and breadth of the country, and allowing the underlying rocks to be seen only in occasional inland peaks, like the *nunataks* of Greenland, and during summer in a narrow in-

terrupted strip along the sea-coast, could not but produce an abrasion of the whole surface vastly greater than that of any local glacier.

It is still possible approximately to estimate at least the minimum thickness which the ice-sheet reached in some of the Scottish valleys. Thus, in Loch Fyne, both sides of the valley are smoothed and striated; nay, the whole of the land between that inlet and the western sea, on the one side, and Loch Long and the Firth of Clyde on the other, bears evidence of vast abrasion. The hill-tops at a height of 1800 feet above Loch Fyne are marked with striæ that run parallel with the valley like those at a lower level. The greatest depth of the loch is 624 feet, and as the whole sides and bottom were probably striated in the same way and by the same agent, the ice was probably more than 2500 feet thick. Maclaren many years ago traced striæ up to heights of more than 2000 feet in the South-west Highlands. Mr. Jamieson estimated that the ice in Glen Spean must have been two miles broad at the surface, and at least 1300 feet deep. The ridge of Ben Lomond is well ice-ground to the top. The finer ice-markings have generally disappeared from exposed rock-faces, though they may often be found by removing the protecting cover of peat or turf. I found them still traceable at a height of 2250 feet, pointing E. 35° S. As the loch is more than 600 feet deep, there could not have been less than 3000 feet of ice lying in that hollow. Similar evidence has been gathered by the officers of the Geological Survey from the mountainous region lying further to the north-east. Ben Venue (2386 feet) and Ben Ledi (2875 feet) are striated up to the very top, and such is the case also with the lofty ridge of Ben Each, Stuc-a-Chroin, and Ben Vorlich between Lochs Lubnaig and Earn. There can be no doubt that all this region was buried under a mass of ice more than 3000 feet thick, which moved in a general south-easterly direction into the Lowlands.[1]

[1] *Scottish Geographical Magazine*, vol. xvi. (1900), p. 229.

But in the North-western Highlands, where the mass of high ground was greater and the snowfall heavier, the ice-sheet not improbably attained even greater dimensions. Rocky crests are there found to be striated all along the watershed of the country up to heights of 3000 feet and upwards. These striations prove the mass of ice to have been more than 3000 feet thick, so as to leave possibly none of the present mountain-tops unburied. Not only so, but from the evidence of the blocks that have been transported across the watershed from lower ground on the east side in Sutherland and Ross, it is clear that the ice-shed did not coincide with the present watershed, but lay to the east of it, and that there the snow and ice gathered in enormous bulk, streaming thence westward across the ridges and through the cols and glens into the Atlantic, as well as down into the eastern plains and the basin of the North Sea.

So long a lapse of time has passed since the last glacier vanished from the mountains of Scotland that it is impossible to contemplate without the keenest astonishment the singular freshness of the polished and striated surfaces which the ice left behind it. From mountain-top to below sea-level the ice-worn polish, striæ and groovings are often as fresh as those by the side of a living glacier. Of course it must be remembered that surfaces now exposed to the air may have been protected for ages by a cover of detritus only comparatively recently removed. But in many cases we can see that for a very long time there can have been no such protection. On mountain-tops quartz-veins may be found with the polish and striæ still well preserved, projecting a quarter of an inch or more above the surface of the surrounding schists. The progress of decay has lowered these schists to that extent, but has not been able to destroy the markings left by the ice on the more durable quartz-veins.

The quartzites of the west of Sutherland and Ross, as might be expected from their remarkable durability, have retained in singular perfection the polish and fine striæ imprinted on them

by the ice-sheet. The summits capped with these rocks have preserved their ice-worn surfaces so well at heights of even 3000 feet, that where they plunge in precipitous sheets down the mountain-sides they cannot be walked on. Even the sure-footed red-deer, when tempted to cross these declivities, often lose their hold and are dashed headlong to the bottom.

Again, where the ice-worn surfaces descend into water, they are often astonishingly perfect, though in positions wherein they might be thought peculiarly liable to disintegration. Every traveller along the west coast of Scotland may gather scores of fresh examples of this singular survival, if he will avoid places where shingle accumulates, and select more especially rocky shores somewhat sheltered from prevalent storms. Many good illustrations are to be seen in the district around Oban. The west side of the Island of Kerrera affords them in great perfection, and a striking display of them may be observed along the margin of Loch Linnhe and its tributary fjords. Thus, a little to the west of the landing-stage at Ballachulish on Loch Leven, a vertical face of rock that has been ice-polished and scored longitudinally, rises like the side of a breakwater out of the sea which for many a long century has been beating upon it. The same durability may be observed by the sides of fresh-water lakes. Nowhere is it more impressively exhibited than along the north-eastern edge of Loch Maree. Huge rounded bosses of gneiss there shoot out of the lake and mount up the sides of the mountain Slioch. They have been horizontally scored and polished by the great body of ice which once filled the loch and rose high along the flanks of the hills on each side. The striæ have been well preserved for a height of 20 or 30 feet above the level of the lake, but are freshest towards the surface of the water and below it. Yet there can have been no protecting cover of detritus there, for the lake is deep. Possibly in this case as well as along the sea-margin the ice-worn surfaces were long protected by being

submerged, and their exposure to the weather dates only from the last uprise of the land.

From the radiation of the striæ on the rock-surfaces, as expressed on the map (Plate IV.), it is quite possible to realise the main movements of the Scottish ice-sheet as it crept seaward. From Cape Wrath to the south-west of Ireland one vast glacier pushed out into the Atlantic, where it broke up into icebergs that probably drifted away to the north with the prevalent winds and currents. The Firth of Clyde was choked with deep ice which, burying Arran, Bute, and the other Clyde islands,[1] moved steadily southward, and joined by the mass that drained from the uplands of Galloway, the Lake Country, and Wales, filled up the basin of the Irish Sea. From the Southern Highlands, the ice marched south-eastwards across the chain of the Ochil Hills, and uniting with that which streamed away from the hills of Lothian and Peebles, went out eastwards into the basin of the North Sea. There the southern half of the Scottish ice-sheet appears to have met with that portion of the Scandinavian ice which crept southwards, and to have marched onwards with it along the east of England nearly as far as the valley of the Thames. From the eastern Grampians, the drainage was towards the east and north-east, while a great body of ice streamed northwards into the Moray Firth, passing north-westwards across the low plains of Caithness and the Orkney and Shetland Islands, and forming with the Norwegian ice-sheet a vast glacier that stretched probably in one unbroken wall of ice for some 1500 miles from Cape Clear to beyond the North Cape.

Among the many contrasts which geology reveals between the present and the past there is surely none that appeals more vividly to the imagination than that which the records of the Ice Age bring before us. These records are so abundant, so clear and so indisputable, that there can be no hesitation in

[1] Fragments of the peculiar rock of Ailsa Craig are found along the east of Ireland down as far as the coast of County Waterford.

accepting the picture which they present to us of the condition of this country at a comparatively recent geological period. Everywhere the trail of the ice meets our eye and sets us thinking of the difference between what is now and what was so lately, that there has not yet been time for nature to efface its vestiges. The contrast perhaps appeals most to our sense of wonder when it meets us among scenes rich in human associations and full of the life and bustle of modern civilisation. To sit, for instance, on one of the Highland hills that overlook the Firth of Clyde, and watch the ships as they come and go from all corners of the earth; to trace village after village, and town after town, dotting the coast-line far as the eye can reach; to see the white steam of the distant railway rising like a summer cloud from among orchards and cornfields and fairy-like woodlands; to mark, far away, the darker smoke of the coal-pit and the iron-work hanging over the haunts of a busy human population; in short, to note all over the landscape, on land and sea, the traces of that human power which is everywhere changing the face of nature;—and then to picture an earlier time, when these waters had never felt the stroke of oar or paddle, when these hillsides had never echoed the sound of human voice, but when over hill and valley, over river and sea, there had fallen a silence as of the grave, when one wide pall of snow and ice stretched across the landscape; to restore, in imagination, the vast ice-sheet filling up the whole wide firth, and creeping slowly and silently southwards, and the valley-glaciers into which this ice-sheet shrank, threading yonder deep Highland glens, which to-day are purple with heather and blithe with the whirring of grouse and woodcock; to seal up the firth once more in ice as the winter frosts used to set over it, and to cover it with bergs and ice-rafts that marked the short-lived Arctic summer; to bring back again the Arctic plants and animals of that early time, the reindeer, the mammoths, and their contemporaries; and thus, from the green and sunny valley of the Clyde, with all its human associations, to pass at

once and by a natural transition to the sterility and solitude of another Greenland, is an employment as delightful as man can well enjoy. The contrast, though striking, is only one of many which the same district, or indeed any part of the country, presents to a geological eye. And it is the opening up of these contrasts, based as they always must be upon a careful and often a laborious collection of facts, which entitles geology to be ranked at once among the most logical and yet amid the most imaginative pursuits in all the wide circle of science.

Though the abrasion of the surface of the country was the chief work of the great ice-sheets, it is by no means the only record they have left in the present scenery of the Highlands. The amount of pre-glacial detritus and of solid rock, ground away by the passage of the ice across the land and spread over lower levels, must have been enormous. The rivers that issue from Alpine glaciers are thickly charged with fine mud made by the friction of the sand and stones borne along under the ice: and in the Arctic regions the sea is sometimes discoloured for miles from shore by the mud ground down from the surface of the land. In the Highlands, the impressiveness of the evidence from rock-striation as to the former presence of land-ice is greatly increased by the testimony of the abundant ice-borne detritus which is strewn so thickly over the slopes of the hills and the bottoms of the valleys.

Away from the mountains, in such flat tracts as Caithness, the shores of the Moray Firth and of its tributary inlets, and the low land bordering the North Sea, the solid rocks are to a large extent covered with a stiff clay, full of stones that vary in size up to boulders a yard or more in diameter. To this deposit the name of Boulder-clay or Till has been given. It attains its chief development in the great Midland Valley. Hence, perhaps, its detailed description had better be deferred until the surface of that region comes before us for examination. Its origin was long involved in mystery, and though now more clearly understood, still presents difficulties which have not

yet been completely explained. The older geologists called it diluvial, and regarded it as proof of a violent flood, or series of floods, which, sweeping across the country, produced the striation of the rocks by driving over them the stones, sand, and clay that now form the till. The introduction of land-ice into the list of agencies concerned in changing the surface of the country gave a clue to the true history of this remarkable superficial deposit. Its internal structure and its striated stones show it to be the debris of the abrasion by the ice-sheet.

The scenery of the districts where boulder-clay prevails, though tame and monotonous, has certain characteristic features of its own. The surface is specially smooth and undulating, save where some rocky knob or hill protrudes through it. Along a sea-cliff or in a river-bank, the more prominent topographical features to which the deposit gives rise can best be seen. It there forms a line of steep green bank, projecting at frequent intervals into massive turf-covered buttresses, and receding in the spaces between into grassy hollows, furrowed here and there by runnels from above. These strange rampart-like slopes have been entirely cut out by denudation. Their mode of origin, indeed, may be seen still in operation, for the percolation of water through sandy layers in the till loosens here and there a mass of the clay which, slipping down the bank, leaves a semicircular scar of raw clay above, as if a huge spadeful had been dug out of the slope. If not too steep for vegetation, this scar is eventually grassed over and becomes like one of the surrounding verdant declivities, which have probably not changed much for many generations. The fallen portion, with its covering of turf, continues to slide as the water trickles below it, but at last, if it does not reach the stream below, it becomes so far shielded by the coating of grass and weeds which creeps over it. It then remains one of many verdurous mounds and hummocks, mottling the sides and base of the declivity, like the ruins of a set of earthworks older than the steep *glacis* that rises behind them. A sloping

bank of boulder-clay under the wasting hand of time thus assumes a curiously uneven outline. When the action that gave rise to its features ceases for a time, the covering of turf which the irregular surface puts on everywhere is trodden into narrow undulating terraces by the sheep. The confused series of grassy mounds and ridges thus produced looks so much like the work of man, as to have given rise to legends of giants' graves and fairy knowes, or to traditions of ancient camps and tumuli.

The influence of the boulder-clay as an element in the landscape can nowhere be better seen in the region of the Highlands than along the sides of the Cromarty and Moray Firths. It forms there a smooth sloping platform from the foot of the bare high grounds down to the inner edge of the terrace of the last raised beach, where it runs as a steep sinuous grassy bank, sometimes between 250 and 300 feet high, worn here and there into some of its characteristic and fantastic forms.[1] The lowlands of Moray between the hills and the sea owe much of their fertile character to their covering of boulder-clay and gravelly drift. The green rampart-like slopes along the coast, and the steep grassy banks and raw clay "scaurs" along the river-courses, are traceable northward to the far headlands of the Pentland Firth. The high boulder-clay cliffs at Rosemarkie are conspicuous from almost all parts of the Moray Firth. Inland, too, at Tain, the same deposit rises in a line of bold bluffs, that mark the limits of an ancient shore. At the Ord of Caithness it is seen capping the headlands of granitic rock, but northward, where the mountainous tracts of Sutherland sink into the plains of Caithness, it spreads far and wide over the surface, choking up the shallow valleys, and forming green banks in the inner parts of sheltered bays. The Caithness boulder-clay contains abundant fragments of marine shells, which, taken together with the evidence of the

[1] See Hugh Miller's description of this scenery in his *Schools and Schoolmasters*.

ice-markings on the rocks, and of transport furnished by the striated stones, show that the ice crossed the bed of the Moray Firth, and was pushed up north-westward across the plains of Caithness.

In most Highland glens, boulder-clay may be found covering the bottoms, and rising up into the hollows on either side, but becoming more and more earthy as it is traced towards the higher grounds, until it can hardly be discriminated from ordinary moraine-stuff. So distinct is the smooth rush-covered surface of the ground over this deposit, that its limits can often

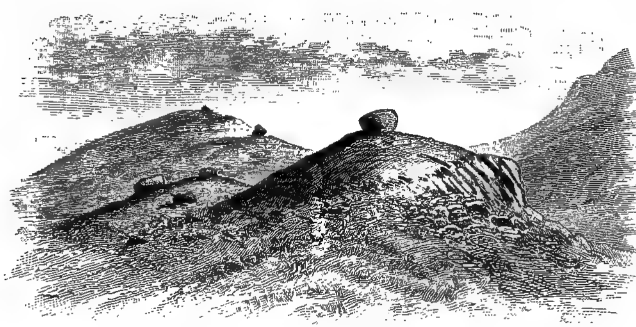

FIG. 75.—Ice-worn knolls and perched blocks, Loch Torridon.

be traced by the eye even at a distance of a mile or more. But the debris of the great ice-sheet in these high grounds has been to a large extent scraped off, or buried by the local glaciers of a later part of the Ice Age, to which reference will be made farther on.

Where the finer detritus dropped by the ice-sheet has been in course of time washed away by rain, the large blocks of rock in the moved material have been left behind. Perched upon the ice-ground hummocks of rock, they now form one of the most characteristic features in many a Highland foreground (Figs. 73, 75, 76). As one of the best localities for the examination of such scattered blocks, the district between Loch Laxford and Richonich in the north-west of Sutherland may be referred to.

There the rounded ice-worn hummocks of Lewisian gneiss are in some places crowded with boulders, perched on the sky-line and poised on the declivities, as if a mere push with the hand would dislodge them. There are one or two places on the high road from which the first view of this singular scenery cannot but fill the traveller with astonishment (Fig. 76). If he cares to climb any of these rocky domes he will find them well smoothed, though the finer scratchings and groovings have for the most part been obliterated by the weather. Yet by uncovering the protecting layer of turf or removing the peaty earth that lies in the hollows, he may almost anywhere detect striation still perfectly legible. The direction of the markings indicates that the ice came down from the great range of heights that lie to the south-east, and the scattered blocks are found to have travelled from the same quarter. Besides boulders of the ancient gneiss from the nearer low grounds, there lie blocks of quartzite from the great escarpments north and south of Loch Stack, and pieces of the younger gneisses that have been carried from the mountains of the interior.

There is probably not a glen in the Highlands that descends from a considerable mass of high ground where such erratic blocks may not be seen, and by studying which, in connection with the geology of the district, we may not be able to trace the path of the ice-sheet or of the later glaciers. Sometimes a single huge mass, measuring 500 cubic feet or more, and weighing 40 tons or upwards, may be found standing alone, like the large schist boulder locally known as "Samson's putting-stane," which lies apparently in dangerous instability on Bochastle Hill west from Callander, on the road to the Trossachs. The erratic blocks become more interesting in proportion as they recede from their parent mountains. I shall therefore reserve a fuller description of them for the account of the Midland Valley.

It is no part of my design in this volume to enter into the history of the Ice Age, except in so far as the scenery

of the country has been influenced by the geological changes which took place during that time. I therefore pass over the records of the fluctuations in the march of the different currents of the ice-sheet, and the evidence for periods of intermittent cold and warmth when, amid great oscillations of climate, the plants and animals of the country varied from cycle to cycle, northern forms at one time coming southward with the augmentation of the snow-fields and glaciers, and

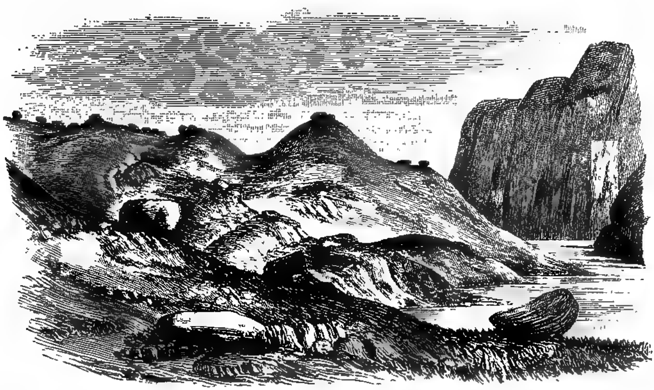

FIG. 76.—Perched blocks on ice-worn hummocks of gneiss between Loch Laxford and Richonich, Sutherland.

southern species at another time migrating northwards as the snow and ice retreated.

The last stages of the Ice Age have left their mark upon the Highlands in a form hardly less fitted to impress the imagination than that of the great ice-sheets. As the vast covering of ice retreated, it came at last to be restricted to the corries and valleys among the higher groups of hills, where it took the shape of local glaciers. Each mass of high ground had its system of glaciers, creeping down the glens, and bearing on their surfaces the heaps of earth and stones they received from the slopes on either side. It is this detritus

which remains as so enduring and striking a memorial of the latest phase of the Ice Age in Scotland.

If the reader will visit a glen where this kind of evidence is conspicuous, he will find a series of mounds, strewn with blocks of every size, some of them larger than many a Highland cottage, stretching across as if to bar access into the recesses of the valley. These ramparts sometimes run without break from one side to the other, and rise to a considerable height. As he picks his way among scattered blocks and ice-worn knolls of rock, he may find himself spurred on by curiosity to discover what may lie behind the last rugged boulder-covered barrier of detritus that towers so formidably in his front. He mounts its outer slope, and on reaching the summit sees below him perhaps a lochan or tarn. The barrier is the latest moraine thrown down by the glacier that once crept down the valley; and it serves still, as at first, to dam back the drainage. From the lake thus formed the surplus waters are now slowly cutting for themselves a pathway through the moraine. The time will come when the stream will have dug its channel as deep as the bottom of the lake, which will then be emptied, leaving a broad flat meadow to mark where it stood (see Figs. 92, 93).

In many a Highland glen it is easy to trace the successive backward steps of the ice as it continued to shrink up into the higher recesses of the mountains. Each band of moraine marks a limit at which the lower end of the glacier continued for a while stationary, melting there and throwing down its accumulated piles of rubbish. Hence, in traversing a series of such moraines, we see the evidence of successive pauses in the retreat of the glacier, until at last we gain the upper end, where the stream of ice finally shrank up into the snow-fields, and where these, as the climate grew warmer, at last melted away.

So abundant are the examples of this characteristic type of Highland scenery that it is hardly needful to single out any by

name. They may be seen on almost any of the great lines of highway through the Highlands, though the more striking illustrations lie rather higher in position, especially at the mouths of the great corries among the loftier mountain groups. As we follow out the vestiges of the valley glaciers, we cannot but be struck with the proofs of how great a mass of ice must still have lingered among the glens that radiate from the chief areas of high ground. We learn, too, how slowly the glaciers shrank back towards their sources. Moraines may be found at every height, from the sea-level up to 3000 feet, or more, above it. No doubt on the whole the oldest of them are those which occur at the lowest levels, though it must be remembered that the greater snowfall of the western coast would allow the glaciers to continue to descend farther seaward on that side than in the eastern parts of the Highlands.

The magnitude of the later glaciers, the continued intensity of the cold long after the great ice-sheet had retired from the Lowlands, and the striking influence which the last stage of the long Ice Age has had upon the configuration of the corries and glens of the Highlands, is impressively seen among the glens to the north and east of Ben Nevis. Let the summer tourist who is in search of the picturesque, and who cares to follow the traces of ancient geological changes, ascend from the shores of Locheil up the valley of the Spean into the wilds of Lochaber. Quitting the shore, with its fringing terrace that marks a former limit of the sea, when the land was some 50 feet lower than it is now, he enters Glen Spean among heaps of moraine detritus, marking former halting-places of the glacier that once filled all the valley. As he ascends the glen, he finds the mounds to have been cut here and there into terraces, flat as meadows, which contrast with the ruggedness of the brown moors around them. These terraces at many successive levels rise high above the present river. The hillsides for several hundred feet upward reveal innumerable fragments of such terraces, which slope with the

general fall of the valley, and evidently date from the time when the glaciers were retreating up Glen Spean, and streams from the melting ice were levelling down the moraine-heaps.

But as the traveller nears Glen Roy, his eye rests upon another and more persistent kind of terrace. Far away up the valley, if the day be favourable for a distant view, he sees a line ruled, as it were, along the steep hillside to the south of the river, and running apparently in absolute horizontality until it is lost to sight. Before turning up Glen Roy to examine the terraces for which that valley has so long been famous, he would do well to continue the ascent of Glen Spean, that he may first of all convince himself by the most striking evidence how extensive were the last glaciers in this mountainous district. A short way beyond Bridge of Roy Inn, the road quits the reassorted glacial rubbish of the valley-bottom, and begins to rise over hummocks of hard schist. These protuberances of rock are smoothed, polished, and striated. They prove that a thick body of ice once passed down the glen, and ground out its sides and bottom. On the right hand, the River Spean brawls and foams in a narrow ravine which, since the ice retired, it has cut for itself through the hard schist (p. 199). One could not find a better contrast of the results produced by the different denuding agents. Along the roadway all is rounded and smoothed as the ice left it; in the ravine below everything is angular and rugged; rains, springs, and frosts are there busy splitting up the schist along its numerous joints, and pushing large blocks of it into the river, where they are dashed against each other and slowly worn away.

Farther up the glen, the ice-worn aspect of the rocks becomes still more striking. When the observer reaches a point opposite the mouth of Glen Treig, he finds that the striæ on the rocks, instead of running down the valley, actually mount the hill to the north, while the glen is cumbered with huge ramparts of glacier rubbish. It was this piece of scenery

which so powerfully impressed Agassiz in his first visit to Scotland, and seemed to him such a demonstration of the existence of glaciers in this country. "I shall never forget," he says, "the impression experienced at the sight of the terraced mounds of blocks which occur at the mouth of the valley of Loch Treig, where it joins Glen Spean; it seemed to me as if I were looking at the numerous moraines of the neighbourhood of Tines in the valley of Chamounix."[1] Since

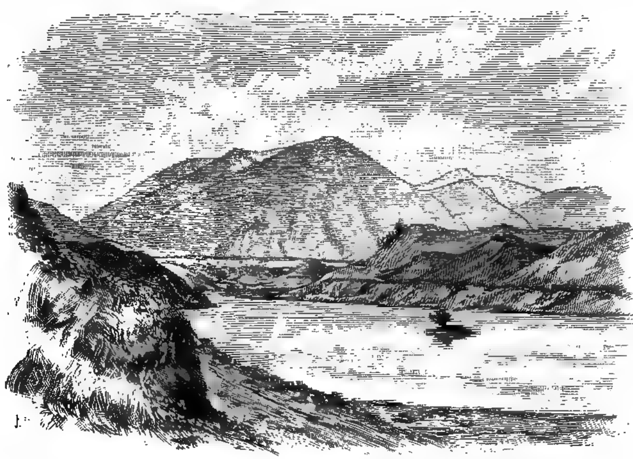

FIG. 77.—View from the lower end of Loch Treig looking across Glen Spean. The terrace visible on the hillside in the distance is the lowest of the Glen Roy shelves, which also comes up to the lower end of Loch Treig.

Agassiz wrote, the district has been again examined in detail by Mr. T. F. Jamieson,[2] Professor Prestwich, and other geologists. The glacier which came down Glen Treig went right across Glen Spean, and ascended the hills for some height on the opposite side. Mr. Jamieson has shown that it not only did so, but that it then branched into two, one part turning to the left down Glen Spean, the other taking to the

[1] Agassiz, "On the Glacial Theory," *Edin. New Phil. Journ.* xxxiii. 222.

[2] See *Quart. Journ. Geol. Soc.* xviii. and xix.

right, through that part of the glen where Loch Laggan now lies, and striking thence into the valley of the Spey. The great size of the Treig glacier is further proved by the magnitude of its moraines. As it issued from its own valley into the wider strath of the Spean, it spread out in a fan-shape, and the piles of rubbish which it carried down on its surface were tumbled over along its edges. There they gathered into mounds, which followed the curving margin of the ice, and still stretch for some miles across the valley to mark where the glacier halted for a long while in its gradual decline. There are two chief lines of moraine, of which the outer one, a narrow, steep-sided mound, rises in some places 60 or 70 feet above its base. Its surface is loaded with fragments of granite, gneiss, and schist of all sizes up to blocks 14 feet long. On the inner line of mound, which is often composed wholly of large blocks, Mr. Jamieson found one mass measuring 26 feet in length, and he compares the moraine to a ruined breakwater.[1] So little finer detritus has been thrown down with these huge erratics that a stone may be dropped for several feet into the dark crannies between them.

The valley of Glen Treig furnishes everywhere proofs of the enormous erosion effected by the ice. Its sides, for a great height above the bottom, are shorn off, rounded, smoothed, and striated, and it encloses a long lake, which lies in a true rock-basin. This lake that has taken the place of the glacier is encompassed at its lower end with moraine-stuff, partly levelled out into terraces. The lowest of the three Glen Roy shelves, to be immediately referred to, ascends to the mouth of the lake.

Returning now to Glen Roy, the traveller should ascend that valley to see what light its famous "Parallel Roads" have

[1] *Quart. Journ. Geol. Soc.* xix. 248. The moraines of this great glacier are well shown on the contoured edition of the Ordnance Survey one-inch Map, Sheet 63.

to cast upon the history of the old glaciers of the Highlands. The same long straight line which, as he drew near to the Bridge of Roy, he noticed running high along the mountain-side on the south of the Spean valley, is now seen to turn up Glen Roy, winding along the slopes of that valley with the same singular horizontality. When he gets several miles up the glen he begins to see traces of two other terraces, until, on reaching a turn of the road, the long deep valley lies before him, with its three bars, straight and distinct as if they had been drawn with a ruler, yet winding into all the recesses of

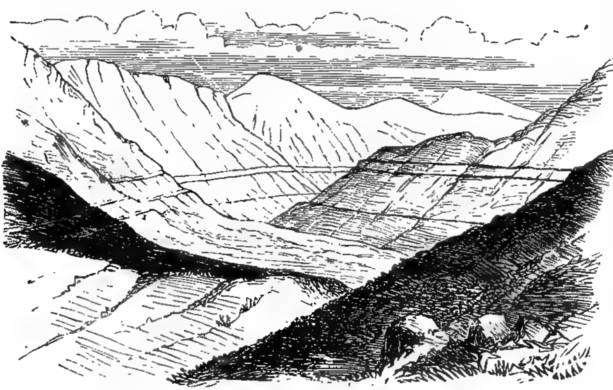

FIG. 78.—View of the Parallel Roads of Glen Roy from the Gap.

the steep slopes, and coming out again over the projecting parts without ever deviating from their parallelism (Fig. 78).

These terraces are distinguishable from a distance chiefly by differences in the vegetation. They are in great part covered with a coarse grass or bent which, especially in autumn, assumes a paler or more golden tint than the verdure of the slopes above and below. Sometimes the terrace forms a boundary between two kinds of vegetation, bent spreading below and heather above. But whenever the profile of the hillside can be seen, the terrace is found to be marked by a narrow flat shelf or notch.

The "Roads," so long a subject of wonderment and legendary story among the Highlanders, and for so many years a source of sore perplexity among men of science, are now satisfactorily explained. Each of them is a shelf or terrace made by the shore-waters of a lake that once filled Glen Roy. The highest is of course the oldest, and those beneath it were formed in succession, as the waters of the lake sank. They are seen not only in Glen Roy. A little beyond, where the first good view of the glen is obtained, a hollow opens through the hills on the left side of the valley, marked on the maps as the Gap (Fig. 78). This hollow forms a short col between Glen Roy and a small valley that strikes away to the south-west into Glen Collarig. Standing on the top of the ridge, the observer looks up Glen Roy on the one side, and down this narrow valley on the other, and he can mark that, while the lowest of the parallel roads in Glen Roy runs along the hillside a short way below him, the two upper roads come through the hollow, and wind westward into Glen Collarig, so that the old lake not only filled up Glen Roy, but also some of the other valleys to the west. Until Agassiz suggested the idea of a dam of glacier-ice, the great difficulty in the way of understanding how a lake could ever have filled these valleys was the entire absence of any relic of the barrier that must have kept back the water. Mr. Jamieson showed, however, that Agassiz's suggestion is fully borne out by the evidence of glacial striæ and moraines, both in Glen Spean and in the valley of the Caledonian Canal. The latter valley seems to have been filled to the brim with ice, which, choking up the mouths of Glen Gluoy and Glen Spean, served to pond back the waters of these glens. The Glen Treig glacier, in like manner, stretched right across Glen Spean and mounted its north bank. When the lake that must thus have filled Glen Roy and the neighbouring valleys was at its deepest, its surplus waters would escape from the head of Glen Roy down into Strath Spey, and at that time the uppermost beach or

parallel road (1155 feet above the present sea-level) was formed.[1] The Glen Treig glacier then shrank a little, and the lake was thus lowered about 78 feet, so as to form the middle terrace, which is 1077 feet above the sea, the outflow being now by the head of Glen Glaster (Gleann glas dhoire), and through Loch Laggan into the Spey. After the lake had remained for a time at that height, the Glen Treig glacier continued on the decline, and at last crept back out of Glen Spean. By this means the level of the lake was reduced to 862 feet above the sea, and the waters of Glen Roy joined those of Loch Laggan, forming one long winding lake, having its outflow, by what is now the head of Glen Spean, into Strath Spey.[2] While this level was maintained, the lowest of the parallel roads of Glen Roy was formed. As the climate grew milder, however, the mass of ice which choked up the mouth of Glen Spean, and ponded back the water, gradually melted away. The drainage of Glen Roy, Glen Spean, and their tributary valleys was then no longer arrested, and as the lake sank in level, the streams one by one took their places in the channels which they have been busy widening and deepening ever since. Such seems to have been the history of the mysterious "Parallel Roads of Lochaber." Instead of tracing back their origin to the days of Fingal, they stand before us as the memorials of an infinitely vaster antiquity—the shores, as it were, of a phantom lake, that came into being with the growth of the glaciers, and vanished as these melted away.[3]

[1] The col between the head of Glen Roy and Glen Spey is marked on the Ordnance Survey Map as 1151 feet—that is, 4 feet lower than the highest terrace. The outflow of the glacier lake into Glen Spey must have been by a very shallow channel.

[2] The col between Glen Spean and the Spey is marked on the Ordnance Map as 848 feet—that is, 14 feet below the level of the lowest of the Glen Roy shelves. A remarkable feature about it is its proximity to the River Pattack, which almost touches it—a curious case, already noticed, of a large stream descending upon the main watershed of the country.

[3] The reader interested in the history of the Parallel Roads will find the best account of them in Mr. Jamieson's paper already cited. He may also

Other glens in the Highlands contain, on a much less extensive scale, terraces of old lakes, the barriers of which were probably formed by ice. One of the most singular examples may be seen at Auchnasheen in Ross-shire, where a group of terraces extends from the valley of Loch Roshk almost up to the watershed on the high road to Strath Carron, which is a little over 600 feet above the sea (Fig. 79). An enormous mass of snow and ice, accumulating to the east upon the Fannich group of mountains, some of which exceed 3600 feet in height, obstructed the drainage in the upper part of Strath Bran, and not improbably ponded back the water which formed the lake of which the marginal terraces remain at Auchnasheen.

It would be far beyond the limits of this volume to describe, or even enumerate, the various valleys among the Highlands where distinct traces are to be seen of the glaciers of the second period. It may be said, indeed, that there are probably few valleys, descending from the higher groups of mountains, where moraines and *roches moutonnées* are not to be seen. When we ascend a glen which receives the drainage

consult the papers by Agassiz, *Proc. Geol. Soc.* iii. 327; *Edin. New Phil. Journ.* xxxiii. 217; and the *Atlantic Monthly* for June 1864. A somewhat voluminous literature is connected with these singular features in Highland scenery, and various theories have been proposed to account for them. Among the more noted writers have been Macculloch, Thomas Dick-Lauder, Charles Darwin, Professor Prestwich, Professor Tyndall, and Mr. D. Milne Home. The best map of the Glen Roy terraces is the one-inch Ordnance Map (Sheet 63), where the whole district has been delineated with a special view to its geological interest.

More recently, during the progress of the Geological Survey in the district, Mr. J. S. Grant-Wilson has found traces of two lower and smaller lakes in Glen Spean. One of these is marked by a line of terrace at 420 feet, which, on the north side of the valley, may be traced from Tirandrish to the mouth of Glen Collarig in Glen Roy, and, on the south side, from opposite the Roman Catholic Chapel above Roy Bridge along the Spean and up the Cour as far as Lianachan, where the outlet would appear to have been, the channel of the Spean River about Tirandrish being still blocked with ice from the Great Glen. A lower line of terrace, at a height of about 300 feet, marks the position of a later lake, which was about 5½ miles long, and stretched from the foot of Glen Roy to Brackletter, near the foot of the Spean.

of a connected cluster of lofty broad-bosomed hills, we may, with not a little confidence, expect to find, somewhere along its course, mounds of glacier-borne rubbish, or hummocks of ice-worn rock. As above remarked, excellent examples of these characteristic features may be noticed along the chief highways through the Highlands. Thus the traveller who has occasion to pass northward by railway to Inverness, travels along the tracks of several of the larger glaciers. As he ascends the course of the Garry beyond the Falls, bosses of hard quartzite and schist meet his eye, with their surfaces

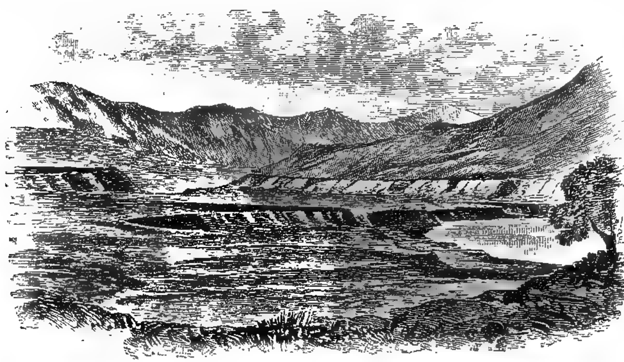

FIG. 79.—Old lake-terraces at Auchnasheen.

smoothed, polished, striated, and heaped over with mounds of rubbish. These mounds increase in number towards the head of the glen, until, at the watershed, the ground from side to side is covered with vast piles of rubbish which are characteristic glacier-moraines. To the west lies Loch Garry—a lake held back by moraine-stuff, which is there cut into a succession of terraces, marking former levels of the water. The moraines, which can be traced to the head of Glen Garry, cross over the watershed, and go down the north side, showing that the glacier of Loch Garry split upon the summit of the pass, and sent one branch into Glen Garry, the other into Glen Truim. The deep Pass of Drumouchter (1490

feet above the sea), where this division took place, is as wild a scene as can be reached in the Highlands by a turnpike road—certainly by far the highest, and on the whole, the wildest pass through which any railway runs in this country. Even the comforts of a railway carriage and a good locomotive do not wholly deprive it of its terrors, for trains are snowed up there almost every winter; but no one who cursorily makes its acquaintance can realise in a rapid railroad transit what the Pass of Drumouchter was in the old coaching days.

Another much frequented route leads the traveller through many miles of glacier ground. The Oban Railway, after leaving Strathire, ascends Glen Ogle amid abundant scattered boulders and moraine mounds. These features continue up Glen Dochart, and are remarkably striking in some parts of that valley as well as in Strath Fillan. Indeed, they may be noticed all the way down to Loch Awe and along the margin of Loch Etive. Each tributary glen which the train passes may be seen to be dotted over with mounds and boulders, showing how all these deep valleys were filled with glaciers.

Not less instructive are the lessons in glacial topography to be learnt along the route followed by the West Highland Railway. The moraines of Glen Falloch are conspicuous, while those between Crianlarich and Tyndrum, and especially the group connected with the glaciers of the Ben Lui mountains, are singularly striking. All along the route round the base of Ben Doran, by the foot of Glen Orchy and the desolate peaty Moor of Rannoch, moraines, erratics, and ice-worn knolls appear on every side. Then come the wonders of Glen Treig and Glen Spean to which reference has already been made.

Much farther north some admirably distinct moraines of the later or valley-glaciers may be found among the higher mountain-groups of Sutherland and Ross. Some of them cannot fail to catch the eye of the traveller by railway or coach-road. The series of moraines which begins above

Strath Peffer and extends along the line of the Highland Railway to the head of Loch Carron may be especially recommended to notice. Or if the geologist branches off from this line at Garve for Ullapool, he will pass a fresh series, some of which form conspicuous features in the landscape, such as the terminal moraine which crosses the valley of the Glascarnoch River below Loch à Garbh Raoin. A beautifully perfect horse-shoe-shaped moraine encircles the outer edge of Loch nan Eilean, south of Beinn Dearg. On the west side of the Dirriemore, huge accumulations of moraine-stuff have been thrown down in the valleys that descend from the mountain-group of Fannich Forest.

A peculiar interest attaches to the evidence that the later glaciers in some districts actually continued to descend to the sea. The relics of these glaciers remain with a singularly picturesque vividness on the eastern coast of Sutherland, where the mountains come down close to the coast, leaving a space between their base and the shore as a long narrow strip of comparatively level arable ground. Of the glens which open upon this selvage of lowland, one of the largest is Strath Brora. It issues from the heart of a lofty group of mountains (Ben Armine, etc.), and, after a course of some thirty miles, terminates at the inner edge of this narrow belt, nearly three miles from the sea. Looking at the map, one would be quite prepared to find glacier-moraines somewhere in this valley, but one could hardly expect to meet with such a striking series of mounds as roughens the plain between the mouth of the valley and the sea. The old glacier of Strath Brora must have spread out over the flat as soon as it escaped from its confinement between the walls of the glen, and the rubbish which it threw down gathered into long rampart-like mounds, that still sweep round in a rude crescent form, from the foot of the hills towards the sea. Within the outer ridges, which are most continuous, there is a confused grouping of mounds, which come together so as to enclose

little pools of water, or basins of peat that mark where similar pools originally lay. Above the mouth of the valley, the same detritus extends towards the loch—a quiet sheet of water lying under the shadow of dark crags, and held back still by the moraine rubbish of the glacier which once occupied its place. It is the relation of the moraine mounds to the sea-level, however, which gives them their greatest interest. They can be traced seawards in straggling hummocks and ridges, until, about a mile south of the village of Brora, one of the mounds is seen to overhang the beach, and a section of it, along with the gravelly beds on which it rests, has been laid bare by the waves. The glacier, in all likelihood, descended to the sea-level when these mounds were formed—an inference borne out by the loose materials on which they rest. So severe did the climate of Scotland still continue, that the valley-glaciers in Eastern Sutherland continued to come down to the shore, until the land had risen to within 40 or 50 feet of its present level.

Not less impressive is the evidence on the northern side of the same county. Loch Eribol, the most striking of the remoter fjords of Sutherland, penetrates inland to the roots of a group of mountains, some of which exceed 2500 feet in height. In these recesses, a glacier was nourished that no doubt at one time filled all the fjord, and went out into the northern sea, circling round the grim precipices of the Whiten Head. It has left its scattered mounds and boulders all along the sides of the loch, while at the head of the inlet the tides rise and fall at the foot of moraine mounds which have not even yet been levelled down.

Again, on the west side of the country abundant evidence may be gathered that the heavier snowfall there continued to allow glaciers to reach the sea after they had elsewhere crept back into the high grounds. At the head of Loch Torridon, for example, the crowded moraines which stream out of all the glens in the lofty group of mountains formed of Torridon

sandstone descend upon the 50-feet beach,[1] and are cut into by the 25-feet beach, so that we there obtain evidence that the glaciers continued to enter the sea at the head of the north-western fjords until after the time when the land had risen to within 50 feet of its present level.

But, perhaps, the continued rigour of the climate during the time of the valley-glaciers is brought most vividly before the mind by the relics they have left among the islands where the area of gathering-ground for snow was small, and where the elevation was often also inconsiderable. In the Island of Arran, for example, moraine mounds and transported blocks crowd the glens and corries of the group of granite hills which culminate in Goatfell. Boulders of granite, which have radiated

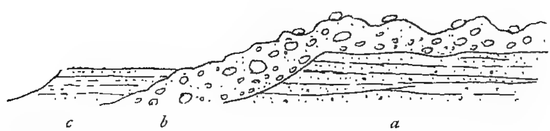

FIG. 80.—Section of moraines and raised beaches, Loch Torridon. *a*, 50-feet beach. *b*, Moraines. *c*, 25-feet beach.

from the main mass of high ground, are now found abundantly strewn over the schists, Old Red Sandstone, Carboniferous, and Triassic formations. Great numbers of these grey blocks are crowded along the slopes and the shore on the eastern side of the island. One of the largest of them, perched on the red sandstone near the edge of the cliff of the raised beach, is shown in Fig. 81. Even the much smaller and lower tract of moorland to the south had its separate glaciers. An admirably well-preserved group of moraines may be seen at the head of Glen Cloy, enclosing an alluvial plain that marks a former lake, and fronting a dark corry on the eastern face of a hill, the summit of which is about 1300 feet above the sea. The mounds are some 300 feet above the level of high-water mark (Fig. 82).

[1] See Mr. L. Hinxman, *Trans. Geol. Soc. Edin.* vi. (1892), 249.

The mountain groups of Mull, Rum, and Skye likewise had snow-fields large enough to feed glaciers that crept down the glens towards the sea. The mass of ice that filled the great cauldron-like recess in which Loch Coruisk lies, pressed outwards through the pass into Loch Scavaig, and no doubt broke up there into little icebergs that floated away out into the Atlantic. The moraines of Glen Sligachan and other valleys leading up into the Cuillin and Red Hills come down to the sea-level. Even the solitary little group of conical hills forming the Island of Hoy in the Orkneys had its glaciers, one of which has left a semicircular moraine half-way down a shady corry looking far over the northern sea.

To one further and much less obtrusive relic of the Ice Age in Highland scenery I would here refer—the Arctic vegetation that still clothes the sides and summits of the Highland mountains. These northern plants can hardly have come to this country across a wide intervening stretch of sea. Their arrival would appear to date back to the time when the floor of the North Sea was either dry land or occupied by land-ice, and when a rigorous climate, extending over the higher latitudes of the northern hemisphere, and driving southward the plants and animals of more temperate character, allowed northern species to replace them. But when at length the wide wintry mantle, that had so long enveloped the mountains and valleys of the Highlands, crept from the sea slowly up the glens; when each glacier shrank step by step backwards into the snow-fields of the uplands, and when finally the snow-fields themselves melted away, the gradual amelioration of climate told powerfully on the plants and animals of the country. The more alpine or Arctic vegetation was by degrees expelled from the warmer plains and lower hills, but remained in the mountains, on whose summits, struggling to maintain its place, it still exists as a surviving relic of that northern flora which once covered the whole British Islands when they were united to the continent.

The northern animals, too, were driven away. Some of them, such as the woolly elephant and the two-horned woolly rhinoceros, thinned in numbers by the change of climate and food, and hunted by primeval man, became extinct; others, such as the reindeer, glutton, lemming, and musk-sheep, have retreated to more congenial haunts in the far north, while the blue hare still remains on our mountains. The sea also

FIG. 81.—Granite boulder from Goatfell, lying on red sandstone, Shore, Corrie, Arran.

furnishes proofs of the change of climate. In the deeper abysses of the western fjords, such as Loch Fyne and the Kyles of Skye, there still linger groups of the Arctic shells which peopled our seas during the Age of Ice. Like the plants, they appear to have been driven out by the migration of more temperate forms, and instead of now ranging from the shore-line downwards, they are confined to the deeper and colder parts of our seas, where they seem to be slowly dying out. A return of the old severe climatal conditions would

doubtless allow the northern forms to recover the area from which those of more temperate climes would then retreat. But we may believe that no such return is impending; that, on the contrary, the last of the Arctic forms, both of mountain-top and sea-bottom, are doomed in the end to disappear, and that species of more temperate character will take their places. And yet, such is the unceasing progress of terrestrial change, alike in organic and inorganic nature, that these latter forms will in all likelihood be themselves displaced by migrations from other parts of the globe, as the climate, or the relative position of sea and land are changed, or as other mutations are brought about by those great geological causes which, though seeming to operate at random, and wholly irrespective of either the animal or vegetable worlds, have yet been mysteriously linked with the grand onward march of life upon our globe.

In fine, the observer who has learnt to follow the trail of the ice-sheets and glaciers that once moved across the Highlands will have been taught at the same time how universally their traces are being obliterated. He is, as it were, admitted within the veil of geological process, and permitted to behold how one great cycle of change is succeeded and effaced by another. While this revelation is almost everywhere made to him, there are some districts where it is more especially clear and impressive. I have been often struck, for instance, with the way in which it presents itself along the shores of Loch Fyne. The hard quartzose rocks opposite Tarbert are beautifully ice-worn and smoothed; their striæ, still fresh and clear, may be seen running out to sea under the waves. The lower parts have been protected from decay, owing partly to the recentness of their upheaval into dry land, and partly to their having been shielded by a coating of boulder-clay, not yet worn away from the bays. But above high-water mark, though the track of the old ice-sheet is still strikingly shown, the rocks have begun to split up along their joints. Hence

the low cliff that rises along the shore is rent into endless chinks and clefts, large angular blocks have been detached from it, and its base is strewn with the ruins. Some of the islands show well the union of the glaciated outlines with this subsequent weathering. They still rise out of the water in long flat curves, like so many whales,—the form that was impressed upon them by the ice; yet they are split across along the joints into open cracks which one might fancifully compare to deep parallel gashes made by the flensers across the whale's back (Fig. 83).

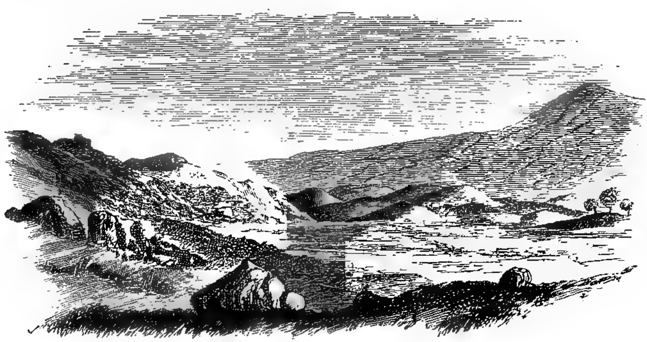

FIG. 82.—Moraines, Glen Cloy, Arran.

Among the higher mountains, where sub-aërial waste advances at its most rapid pace, the obliteration of the marks of the ice may be seen in all stages of its progress. Where a covering of peat or moraine-stuff has protected the rock, the smoothed and striated surface may still be seen as fresh as if the glacier had only just left it. As already remarked, veins of quartz, so persistently durable a material, may be found still to retain the glassy polish and fine scratches impressed on them by the ice, and to project above the surface of the surrounding less resisting rock. But by degrees the influence of air, rain, and frost is corroding the surface of exposed rocks, splitting open their joints, and restoring somewhat

of the rough, jagged, angular forms which the ice had smoothed away. It is unnecessary to multiply instances of a feature of Highland scenery which may be seen more or less distinctly on almost every hillside and valley.

Nor is it needful to do more than allude to the innumerable ravines and river-channels which have been excavated since the ice disappeared, and of which examples have been described in previous pages. The rubbish left by the ice has in many cases completely filled up the pre-glacial river-channels, and since the ice retired the streams have been digging out new courses for themselves, sometimes in that rubbish, sometimes in the solid rock. It can be demonstrated that many deep

FIG. 83.—Ice-worn islets in Loch Fyne, weathering along the parallel joints of the rock.

and wide gorges have been entirely excavated since the retreat of the ice.

Since the Glacial Period came to a close, not only have the various powers of waste been ceaselessly at work upon the land, there has likewise been an upheaval of the country to a height of 40 or 50 feet above the level at which it stood when the glaciers crept back from the mouth of Glen Spean and from the margin of the sea on the coast-line of Sutherland and Ross. The later stages of this rise will be further alluded to in a subsequent chapter in their relation to the kingdom generally. Forests, too, have sprung up and disappeared. Lakes have given place to bogs and peat-mosses. And man, a more rapid agent of change than the elements, has done much to alter the aspect of the Highlands. I think it better, however, to defer the notice of these later

changes until the scenery of the rest of the kingdom has been considered.[1]

[1] It will, of course, be understood that the scope of this volume permits me to treat only of those geological changes of which there are marked proofs in the scenery of the country. Hence I must pass over the evidence of oscillations of level afforded by the sunk forests, and other subjects which, though of great interest, do not specially elucidate the present inquiry.

PART III

THE SOUTHERN UPLANDS

CHAPTER XII

PHYSICAL FEATURES AND GEOLOGICAL STRUCTURE

FROM the iron-bound coast of St. Abb's Head, on the one side of the island, to the cliffs of Portpatrick on the other, there stretches a continuous band of high ground, sometimes called the South Highlands, and which for the sake of clearness has been referred to in the foregoing chapters as the Southern Uplands. This tract forms the most southerly of the three transverse belts in Scottish topography, and though a well-defined region of hilly ground, presents a striking contrast to the Highlands in its lower elevation, and still more in its general configuration. Nevertheless, when looked at from the plains on either side, it rises with conspicuous abruptness into a long line of hills. Its north-western limit in particular is as well marked as the line that separates the Highlands from the Lowlands, between the Clyde and Stonehaven. In East Lothian and Edinburghshire it mounts into the long chain of the Lammermuirs, whose steep bare front, flanked by a line of fault that lets down the rocks of the lowland, seems to project headland after headland into the fertile plains and woodlands below, as a high river-bank rises out of its alluvial haugh, or as a lofty cliff sweeps upward in promontory and bay above the sea. Across the counties of Peebles and Lanark, the edge of these uplands, though still well defined geologically, is sometimes not so marked in the landscape, owing to the rise of the ground in its front. But

in Ayrshire it regains well-nigh all the boldness which marks its course through the eastern counties, and from the head of Nithsdale to the sea at Girvan, it is traceable in the long front of abrupt rocky hills which overlook the coal-fields of Cumnock and Dalmellington, and rise so picturesquely out of the woods and corn-fields of the vale of the Girvan Water. The south-eastern border of the district is less exactly defined, except to the west of the Nith, where it plunges into the sea, and in Berwickshire, where it rises out of the Merse. In the tract between these two districts an occasional gradation from the characteristic features of the great upland country into a mingling of wild moorland and cultivated valley gives a peculiar charm to the landscapes of the Borders. From the Solway to the Cheviot Hills the margin of the uplands is fringed with a line of bold escarpments, which look away over the moors of Eskdale and the Ewes Water.

The Southern Uplands are remarkable for an extraordinary complexity of geological structure. But this complexity is so uniform in its character and so widespread in its distribution that it produces results on the topography such as might be expected only from a much simpler arrangement of the rocks. The region in fact is characterised by a somewhat monotonous type of scenery. It consists almost entirely of hard greywacke and shale, with occasional bands of limestone belonging to the Silurian system. One of the most important recent additions to our knowledge of the geological structure of the region has been made by the officers of the Geological Survey, Messrs. Peach and Horne, who have ascertained that the base of the Silurian series consists of a volcanic group which is brought up to the surface on the crests of the deeper anticlines. Only in the south of Ayrshire and in Nithsdale do these arches open out wide enough to expose the lavas and tuffs for spaces of several square miles at the surface. But from their numerous though limited outcrops, it is evident that these rocks underlie the sedimentary series for hundreds of square miles.

There has been no general or regional metamorphism of the rocks of the Uplands, except of that feeble kind which is usually attendant upon great plication. But they have undergone enormous lateral compression. They have been crumpled up like piles of carpets, have been thrown into a succession of folds running from south-west to north-east, and

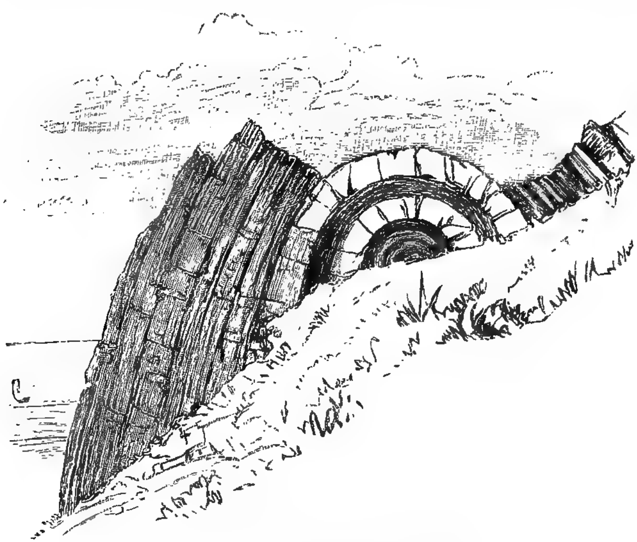

FIG. 84.—Curved Silurian strata, coast of Berwickshire.

have been fractured and thrust over each other in a manner similar to that in which the Highland rocks have been affected.[1]

The cliff-sections where this geological structure is exhibited are among the most instructive to the geologist of any in Scotland. Along the rocky coast of Wigtown and Kirkcud-

[1] See the details of this structure, which was first indicated by Prof. Lapworth, given in great fulness in the Geological Survey volume on *The Silurian Rocks of Scotland*, by Messrs. Peach, Horne, and Teall, 1899 (section 3 on Plate III. of the present volume). The Silurian formations of the region include representatives of each great subdivision of the system from the Arenig up to the Wenlock or even the Ludlow rocks.

bright, on the one side of the country, and of Berwickshire on the other, he will see the massive beds of greywacke and thin hard shales bent into great arches and troughs, or squeezed into little puckerings, and will be able to trace the larger plications from top to bottom of the cliffs, mile after mile along the coast (Figs. 16, 84, 85, 86). He will observe that so frequent and rapid are the plications that the same group of strata, though all the while on end and of comparatively trifling thickness, may extend over a broad space of ground, very much as the leaves of a bound book are made up of numerous foldings of a comparatively small number of sheets. He may here and there detect the anticlines, but in the great majority of cases their tops have been shorn off by denudation, somewhat as the edges of the folded sheets of a volume have been pared off by the bookbinder. And he will learn that in spite of their vertical inclination, the strata of a ridge may often not descend into the valley below, but stretch away in rapid folds at a higher level, so as in some measure to behave as if they were flat, and not on end. So great has been the compression in some places that the rocks have undergone cleavage, and may now be split into parallel laminæ, the direction of which has no reference to the original bedding (Fig. 85).

These Silurian strata are unconformably covered with strips and patches of younger formations. Thus, the Upper Old Red Sandstone lies in bays along the northern edge of the Lammermuirs, caps their summit south of Fala, and ascends from the low grounds of the Tweed up the valley of the Leader. It likewise stretches southward round the flanks of the Cheviot Hills, and in a broken band along the margin of the Silurian region, by Liddesdale, Birrenswark, Carsethorn, and the northern shores of the Solway Firth, nearly as far as Kirkcudbright Bay (Fig. 86). Lying on the edges of the Silurian strata, it fills up what were evidently lines of valley, worn down in the denuded surface of these rocks. In the south-

western part of the Uplands, patches of Carboniferous strata likewise occupy tracts which appear to have been ancient valleys, as in Nithsdale and Loch Ryan. But the most remarkable proofs that rocks of Carboniferous age once extended over much of the Silurian region is supplied by the range of escarpments that run from Birrenswark in Annandale, eastwards through the lofty range of fells between Eskdale and the head of the Slitrig Water, and by the structure of the Sanquhar

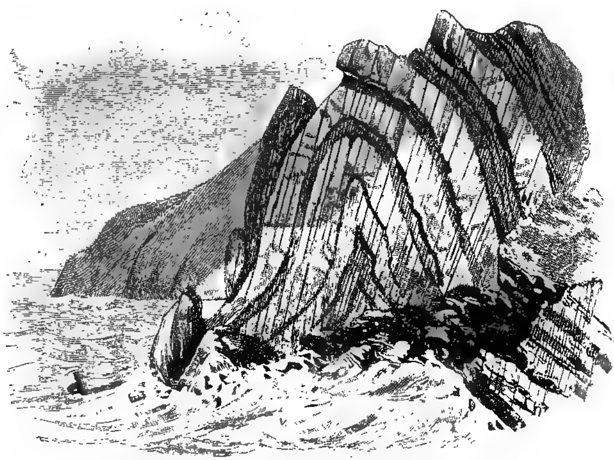

FIG. 85.—Curved and cleaved Silurian rocks, Wigtownshire. The fine parallel oblique lines indicate the cleavage, which is finer in the shales and coarser in the thicker grits and sandstones.

coal-field. The Eskdale and Ewesdale escarpments owe their prominence to the band of volcanic rocks at the base of the Carboniferous system. They look far over the moors to the north, and, with their overlying sheets of Lower Carboniferous sandstone, no doubt once stretched for miles over the Silurian ground. In the Sanquhar coal-field, the Coal-measures lie directly upon the denuded edges of the Silurian strata and have been thrown down by a powerful fault along the east side of the valley (Fig. 87). The total thickness of Carboniferous

strata in the valley is about 1200 feet. If these rocks could be restored to their original horizontal position, they would doubtless completely overspread all the surrounding Silurian hills.

Of younger date are the scattered patches of red breccias and sandstones which lie in the bottom of the valleys of Nithsdale and Annandale, in a little basin among the Leadhills, and in Loch Ryan, and which have been considered to be probably of the age of some part of the English Permian series, though possibly they may include strata referable to the Trias. Wherever a large enough mass of any of these later deposits occurs, it shows itself by a difference in the character of the ground overlying it. In the case of the Permian and Triassic strata, the areas which they occupy have their soil stained a deep red, which is a conspicuous feature in Annandale, in the lower part of Nithsdale, and in the southern part of Dumfriesshire, between Annan and Canobie, where the Triassic groups of Cumberland cross over to the north side of the Solway Firth.

In comparing the geological structure with the external form of the ground, we at once see that though the character of the underlying rocks undoubtedly influences the aspect of the surface, the heights and hollows of the Southern Uplands are certainly not directly due to corresponding uplifts and subsidences. Although the rocks have been intensely folded and puckered, the arches into which they have been thrown do not form the hills, nor do the troughs make the valleys. Indeed, along the crest of the sea-cliffs, we see the ends of the strata cut sharply off by the surface of the country, whether they consist of greywacke or shale, whether they are vertical or gently inclined, and whether they have been thrown into anticlinal or synclinal folds. It is plain that to whatever origin the present irregularities of the ground are to be assigned, they are not due to the upward and downward curvatures of the rocks. It will be seen in the sequel, that these uplands, like the Highlands, are a stupendous monument of denudation; that a vast thickness

of rock has been ground away from their present surface, and that their hollows and hills have been determined by the same powers of waste that have played a like part in the history of the northern half of the kingdom.

The scenery of the Southern Uplands is distinct from that of any other part of Scotland. It maintains, indeed, a great uniformity, and even monotony, throughout its whole extent. No one can journey, however, through Galloway or Carrick, and thence across the moorlands that stretch north-eastward to the North Sea, without observing that this long chain

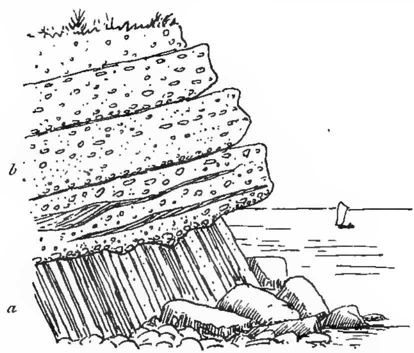

FIG. 86.—Section showing the unconformability of the Upper Old Red Sandstone (*b*) on Upper Silurian strata (*a*), Shore, near Netherlaw Point, Kirkcudbright.

of high grounds divides itself naturally into two not very unequal portions, each of which, while retaining the same family likeness, possesses, nevertheless, certain individual and distinguishing features of its own. The valley of the Nith passes completely across the region, and its course serves as an approximate boundary-line between these two districts. This may be partly seen, even from a glance at the map. The tracts that lie between the Nith and St. Patrick's Channel will be observed to be broken up into irregular groups of hills, dotted over with lakes and tarns, but traversed by few large streams. The country between Nithsdale and St. Abb's Head,

on the other hand, will be found to consist of long, connected chains of heights, nearly destitute of lakes, but with numerous confluent valleys, whose united waters, after a course of many miles, enter the sea as important rivers—the Clyde, Tweed, Esk, and Annan.

The north-eastern half of the Silurian belt, from Nithsdale to the North Sea, may be regarded as a wide undulating table-land, cut into coalescing ridges by a set of valleys which are usually narrow and deep. It has no determinate system of hill-ranges, the grouping of its eminences seeming, in most cases, to have been defined by the circumstances which aided or retarded the excavation of the intervening hollows. Thus its seaward portion, forming the heights of Lammermuir, when seen from the plains of East Lothian, has a long undulating summit, with an average level of 1500 or 1600 feet above the sea, and rises abruptly, with a steep bare slope, high above the rich champaign country that stretches to the shore. Standing on the north-western verge of these heights, on such an eminence for instance as Lammer Law (1733 feet), the spectator sees below him, to the north and west, a rolling plain of woodlands and corn-fields, dotted with villages and mansions, down to the edge of the blue firth, and ranging westward beyond the crags and hills of Edinburgh. But he has only to turn round to the south and east to look over a dreary expanse of bare hill-top and bleak moor—wide lonely pastoral uplands, with scarce any further trace of human interference visible from this height than here and there a sheep-drain or grey cairn. Far away south, beyond the limits of this solitary region, the Eildon Hills, Rubers Law, and all the long chain of the Border heights eastward to the Cheviots, rise up with a softened outline from the green vale of Tweed. The surface of the Lammermuirs, like that of the greater part of these uplands, is singularly smooth. It is coated with short heath or coarse grass, save where a mantle of peat covers the hollows, or where the streams keep open their channels through the boulder-clay or rock. So smooth, broad,

and grassy are these hill-tops, that they may be traversed from Lammer Law to the eastern end of the chain without showing anywhere the solid rock at the surface; and but for the distant view of the rich lowlands lying far below, the traveller might walk mile after mile in the belief that he was passing over a piece of wild moorland, such as occurs in the lower parts of the country, instead of the summit of a chain of hills some 1500 or 1600 feet above the sea. If, however, while moving along the ridge he approached its edge, especially towards its western end, he would find that it descends abruptly into the plains, and is deeply trenched with gullies and narrow glens, through which its drainage escapes to the low grounds.

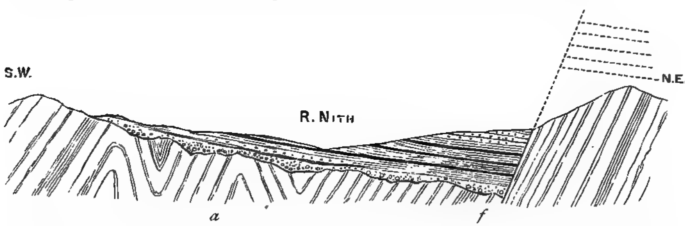

FIG. 87.—Section across the Sanquhar Coal-field. *a*, Silurian rocks covered by Coal-measures. *f*, Fault.

These heights of Lammermuir may be taken as a fair sample of the general scenery of the country between the North Sea and the vale of the Nith. Yet, in the higher parts of the district, the smoothness and verdure of the hills are here and there exchanged for bold rocky scarps, bare crags and cliffs, and deep narrow defiles, like the romantic Pass of Dalveen among the Lowther Hills, that remind us now and then of parts of the Highlands. Where the ground rises into the group of Broad Law and Hart Fell, more rugged features are seen. We there come upon the deep dark glens that lead into Moffatdale, as those of Black Hope, Carreifran, and the Grey Mare's Tail; the solitary glen of the Talla, and the crescent-shaped cliffs of White Coomb and the Loch Craig, that "frown round dark Loch Skene."

Yet, though the flanks of the hills which form the higher parts of the uplands are thus cut into rocky declivities and narrow defiles, the prevailing character of a table-land is still impressively retained. Let the geologist ascend to the top of the Broad Law, which, at a height of 2754 feet, overlooks the whole of the surrounding country. The summit of this hill is a wide level moor, of which some 300 or 400 acres lie above the contour line of 2500 feet. If it stood at a lower level, it is flat enough to be used as a race-course. From this elevation the eye ranges over a vast sweep of hills rising one after another, with long smooth coalescing summits that form, where seen from this height, a wide table-land. Were it not, indeed, for the deep valleys that can be traced threading their way through these hills, a stranger spirited away and set down on the Broad Law might easily imagine that he had been taken to some league-long moorland in the lowland plains. And even if he cannot get to the top, save by the prosaic and somewhat toilsome process of climbing, his walk, while it will give him a lively sense of the height of the table-land, will not diminish the wonder with which he beholds the landscape, nor will it in aught lessen his conviction that this great expanse of elevated moorland must at one time have been an undulating plain, and that but for the scooping out of its valleys by sub-aërial waste, it would be a great plain still. Such broad flat tops in the more easterly part of the Silurian uplands are counterparts, on a smaller scale, of those that rise so conspicuously among the eastern Grampians. Like these, they seem to remain as fragments of a once continuous table-land.

Nor is the aspect of the valleys that wind through the north-eastern half of the uplands less characteristic than that of the hills. The heathy or peaty covering that often lies along the flat summits gives place to a coarse sward, as the hills slope towards the streams, which they do sometimes steeply, sometimes gently, yet almost always with a smooth grassy surface, broken now and then by a scar or scree of grey rock, or

enlivened with patches of waving bracken. Where they approach each other closely, they form such narrow deep glens as those of the Talla and Manor Waters (Fig. 88), and where they are less shelving and wider apart, alluvial meadow-lands, like those of the Tweed, spread out in the broader space between their bases. Except by the water-courses, or where they have been planted along the lower parts of the hills, chiefly as a shelter for sheep, there are no trees. Nor do we meet with that union of crags, scars, and broken ground, with masses of purple heather, ferns, and wild-flowers, which enters so largely into a

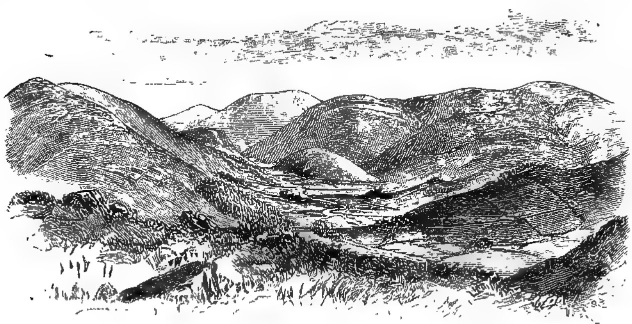

FIG. 88.—The Southern Uplands around the Vale of the Manor Water, seen from the top of Cademuir (1314 feet), south of Peebles.

typical Highland landscape. It is, in short, a smooth, green, pastoral country, cultivated along the larger valleys, with its hills left bare for sheep, yet showing enough of dark bushless moor to remind us of its altitude above the more fertile plains that bound it on the northern and southern sides.

The south-western half of the Southern Uplands, stretching from Nithsdale to Portpatrick, though marked by the same great features of a wide table-land cut into distinct ridges by systems of valleys, yet shows a good many local peculiarities. It rises in Galloway into a cluster of mountains, of which the highest, Merrick, is 2764 feet above the sea—the most elevated ground in the south of Scotland. These heights are more

Highland-like in their wildness than those of any other part of the south of Scotland. Their tops indeed are smooth, but their sides are often deeply gashed with gullies and glens (Fig. 9), or scarped with abrupt precipices. No scenery in the whole of the uplands can compare, for naked and rugged grandeur, with the glens of the Merrick and Kells hills. There are no trees, no cultivation, and but little trace of man. The mountains descend in a wilderness of shattered crags into dark glens, where the streamlets are often caught in little tarns, or dash in foaming cataracts over ledge and cliff. Between these hills and the coast of Wigtownshire lies a region of rough moor, mottled with endless moraine hummocks and scores of gleaming lakes.

Some of the outer features of this region will be again alluded to in connection with its old glaciers. Its greater wildness is doubtless to be mainly attributed to its geological structure. The Silurian strata have been invaded by some large masses of granite, around which they have undergone a far more decided metamorphism than anywhere else in the southern counties. This metamorphism is unequal, but in some places has gone so far as to convert the greywacke and shale into mica-schists. Presenting great differences in their powers of resisting decay, the rocks have yielded unequally to disintegration; the harder portions project in rocky knolls, crags, and cliffs, while the softer parts have been worn down into more flowing outlines. The highest summit, Merrick, consists of Silurian strata much altered by proximity to the granite, while the rest of the more prominent heights—Rinns of Kells (2668 feet), Cairnsmore of Carsphairn (2612), and Cairnsmore of Fleet (2331)—are formed of granite. Nevertheless, these more rugged features do not efface the traces of that undulating line which connects hill-top with hill-top in one wide sweep of table-land. Seen from the western side of the moors, or from the plains of Ayrshire, the glens, corries, and defiles disappear, and we trace only a long mass of high ground, sloping gently away from a central ridge (Fig. 89).

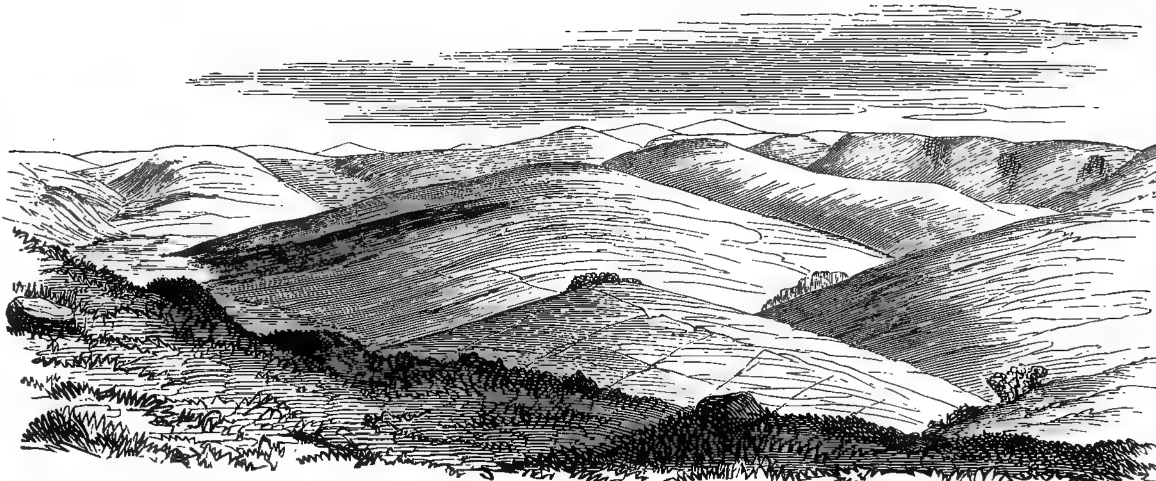

FIG. 89.—Outline of the Southern Uplands, seen from above the Village of Barr in Southern Ayrshire. The highest peak in the distance is Merrick, the most elevated point in the south of Scotland.

Some of the individuality in the scenery of the south-western part of the Southern Uplands may perhaps be attributable to a meteorological cause. As has been already suggested in the case of the Western Highlands, it may be that to the heavier rainfall, with formerly the greater snowfall, and the consequent more active denudation in the south-western counties, we should ascribe a considerable share in the production of the more rugged and Highland-like aspect of that region. Certainly a curious parallel may be traced between the gradation from the eastern to the western type in these two tracts of Scotland. The traveller who advances from Berwickshire to Galloway meets with a similar but feebler repetition of the change of hill-form which he can trace from the eastern Grampians into the west of Inverness-shire and Argyll.

No part of Scotland has been so much sung in the national poetry as these pastoral uplands of the southern counties, from the days of the older ballads to the fugitive pieces of last week's newspapers. I venture to think that no part of the country has been at the same time so misunderstood—praised for beauties which it cannot claim, and maligned for supposed defects which rightly understood constitute much of its charm. What is it in the landscapes of Tweed and Gala, Yarrow and Ettrick, that has inspired so many songsters? If we expect to recognise the source of inspiration in the scenery alone, we shall assuredly fail to find it there. I presume the usual feeling of those who begin in adult years their personal acquaintance with this pastoral country is disappointment, more or less distinctly felt and acknowledged. Wordsworth's exquisite *Yarrow Visited* undoubtedly conveys a truthful picture of the disenchantment which actual contemplation of the scenery is apt to produce in the minds of those who have formed their preconceived impressions from poetry and romance. When Washington Irving was taken up by Scott to a commanding height around which all the borderland lay extended, he could not conceal his mortification. "I saw," he says, "a great part of the Border

Country spread out before me, and gazed about me for a time with mute surprise, I may almost say with disappointment. I beheld a mere succession of grey waving hills, line beyond line, as far as my eye could reach, monotonous in their aspect, and so destitute of trees, that one could almost see a stout fly walking along their profile; and far-famed Tweed appeared a naked stream, flowing between bare hills, without a tree or thicket on its banks."

The casual traveller to this region usually finds at least three fundamental faults with it—featurelessness, treelessness, and monotony. To him it is a smooth bare sweep of bushless hills, rising ridge beyond ridge, interminable in their continuity of tame outline and oppressive in their sameness of colour.

For my own part, I have never been able to understand the charge of want of feature. True, the hills do not mount into crests or peaks, nor are their sides abundantly gashed with ravines, or roughened with many crags and precipices. Yet, of feature, and most expressive feature, every one of them is full. Nowhere else in Scotland can the exquisite modelling of flowing curves in hill-forms, due partly to the sculpture of underlying solid rock, and partly to the lines assumed by accumulating detritus, be so conspicuously seen. These characters are not obtrusive, indeed, but perhaps on that very ground they afford a keener pleasure to the eye that has been trained to detect them.

With regard to the charge of treelessness, it should be borne in mind, I think, that trees have their appointed places in landscape, where they are altogether admirable, but that there are other places where their presence in any number is felt to be inappropriate. Much, of course, depends upon personal taste and habit in such matters. To my own eye, for example, the hills in Rhineland, so densely wooded to the top that not a single feature of them can be seen, are examples of the abuse of trees in landscape. It would be intolerable so to bury up the beauty of the Border hills. All that a true lover

of that region will allow is a straggling copse of pensive birks, creeping upward from the valley, or nestling green in some shady stream-watered dell on the bare hillside. To imagine that we should improve the look of the landscape there by large plantations of timber, would be about as natural as to believe that we should add to the grace of the Apollo Belvedere by putting him into a great-coat.

The so-called monotony of these softly undulating hills constitutes, I do not doubt, one main element in the peculiar fascination which they have always exercised upon minds of a poetic cast. From the sky-line on either side, gentle but boldly drawn curves of bent-covered moorland sweep down into the grassy meadow on the floor of the valley. These are architectural forms of the hill-slopes, and remain distinct at all seasons of the year. But their beauty and impressiveness vary from month to month, almost from hour to hour. For the most part they are aglow with colour, now purple with heather-blooms, now bright-green with bracken, now yellow with golden bent, now deepening into orange and russet as the early frosts of autumn lay their fingers on the ferns. And these colours are suffused, as it were, over the slopes, like a thin enamel, that never conceals the modulations of their form. In winter, when the ground is covered with snow, the endless diversity and grace of the curves stand out in naked beauty and offer to the student of hill-forms an admirable lesson. I cherish, as a lifelong possession, the recollection of the winter aspect of these uplands when I was snowed-up for a week under the hospitable roof of old Tibbie Shiels at St. Mary's.

The long sweeping lines of form and colour, which would be utterly lost under a covering of trees, plunge down into the flat meadows of the valley through which a clear stream is ever murmuring. We wander down the valley, and find other similar streams emerging from narrower valleys, on either hand, where still the same forms of slope and ridge rise against the sky. The very bareness of the landscape becomes

itself a charm, allowing the soft gentle outlines of the hills to have full play upon the fancy. There is a tender grace in the landscape that is offended by the protrusion of no harsh feature, no abrupt crag or yawning ravine. Moreover a pleasing loneliness broods over it all, which, in the case of sterner scenery, becomes oppressive and almost insupportable. The silence is broken fitfully by the breeze as it bears back the murmur of the distant brook, or by the curlew screaming from the nearer hill. The very sounds of the valley—the plaintive cadence of the river, and the low sad sough of the wind along the slopes — combine to produce that tone of melancholy which seems so characteristic and so inseparable from these pastoral valleys.

But who can wander by Yarrow or Ettrick without feeling that the strange witchery with which the scenery fascinates us, springs mainly from what can neither be seen nor heard—from the human associations that have consecrated every spot within its borders. No one can feel this more deeply and gratefully than I. And yet am I none the less convinced that these human associations, in so far as they are the offspring of poetic imagination, owe far more than is generally recognised to the peculiar physical features of the region in which they took their birth, and which, indeed, often suggested as well as coloured them. To the influence of the scenery, amid which the deeds of daring were done, and the tales of love were told, the ballads and songs owe much of the distinguishing qualities of the Border minstrelsy. The recognition of this influence, however, will in no way lessen the pleasure with which, indulging in dreamy thoughts of the past, we linger by Gala and Tweed, Ettrick and Yarrow, with their castles, and peels, and chapels, lonely and grey, and the traditions that seem to cling with a living power to every ruin and hillside. And though, sharing in Wordsworth's experience, we may "see but not by sight alone," and allow "a ray of fancy" to mingle with all our seeing, we come back to these bare hills and quiet green

valleys ever with fresh delight, and find that as we grow older they seem to grow greener, and to enter with a renewed sympathy into the musings of the hour.[1]

[1] To the reader who has not wandered through these uplands in sunshine and storm, I cannot hope to convey an adequate idea of their fascination. Besides the interesting passage in the *Life of Scott* above referred to, and Wordsworth's delightful poems of *Yarrow Unvisited* and *Yarrow Visited*, many admirable descriptions of the scenery of these regions will be found in Scott's novels, as, for instance, in *St. Ronan's Well*, *The Abbot*, and *The Bride of Lammermoor*.

CHAPTER XIII

THE SOUTHERN TABLE-LAND AND ITS VALLEYS

FROM what was stated in Chapter VII. regarding the levelling down of the convoluted and fractured rocks of the Highlands into a great plain or base-level of erosion, the reader will have no difficulty in recognising, from the broad similarity of structure, that the same process must have been at work upon what are now the Uplands of the southern counties. The lesson of vast denudation, taught by every Highland mountain-top, is brought home to us not less vividly here. A casual scrutiny suffices to make it clear that these long flat summits, instead of being made by the broad surfaces of horizontal strata, have been in reality planed down across the upturned edges of contorted greywackes and shales. In crossing a smooth hill-top among these uplands, we pass over bed after bed, tilted on end, crumpled, inverted, broken; yet the whole complex mass has been shorn away to a common level. By prolonging the truncated arches of the rocks, some idea may be formed of how vast an amount of material must have been worn away, and how entirely the surface of these high grounds has been fashioned by denudation (see Section 3 on the Geological Map, Plate III.). As was maintained in the discussion of the similar geological structure of the Highlands, the cutting of such a great undulating plain out of hard rock was probably a prolonged process, continued during many geological periods, but no doubt interrupted by many upheavals and subsidences,

and was mainly carried on by sub-aërial waste and completed by the waves of the sea.

At what geological date did this widespread denudation begin? Within certain limits it is possible to answer this question. As the rocks are of Silurian age, their denudation must be later than Silurian times. They are overlain in the south-western parts of the uplands with the Lower Old Red conglomerates, sandstones, and volcanic rocks, which are likewise thrown down against their flanks by powerful faults. If we try to restore the relative positions of the various formations before the dislocations took place, we see that the younger deposits must have extended far over the denuded edges of the older, and must have buried them to a depth of hundreds, or even thousands of feet. Again, in the north-eastern part of the uplands, the tracts of Upper Old Red conglomerate and sandstone are only fragments of a more continuous sheet that once spread far and wide over that area of the Silurian region. Like the lower division of the same system in Ayrshire and Lanarkshire, these deposits are made of the waste of the underlying rocks, and by their contents and position they show that before they were laid down, the contortion of the Silurian rocks and considerable disturbance of the Lower Old Red Sandstone had taken place. We are thus taught that the great earth-movements which plicated the Highlands and Southern Uplands were probably parts of one continuous and, in a geological sense, contemporaneous succession of disturbances, which were accomplished during a long series of ages represented by the highest Silurian and lowest Old Red Sandstone deposits. That they were in the main completed before the conglomerates of the latter series were deposited is demonstrated by the composition of these younger accumulations and their strong unconformability upon the older rocks.

The first ascertainable facts, therefore, as to the levelling down of the southern table-land are that in the south and west it was effected partly before and partly during the time of the

Lower Old Red Sandstone, and that in the north-east it was still going on in the time of the Upper Old Red Sandstone. But there is likewise evidence of the elevation of the region, and of the prolonged denudation of these younger formations, even as far back as Palæozoic time. We know, for instance, that the thick masses of Lower Old Red conglomerate, sandstone, and volcanic rocks had been stripped off from the uplands about the head of Nithsdale before the period of the Coal-measures, for the coal-bearing strata of Sanquhar rest directly upon Silurian greywacke and shale, and appear to have extended far over that region (Fig. 87). Again, the scattered patches of Permian breccia point to the wearing away of this Carboniferous cover in the next geological period.

The history of the evolution of the topography of the southern table-land is thus, as in the Highlands, long and complicated. We have not to deal merely with a denuded plateau, raised by a single uplift within the influence of sub-aërial waste and valley-erosion, but with a region which has again and again been upraised, worn down and buried under piles of its own ruin. We must remember also that only a fragment of the table-land now remains. On the north it has been cut through by a system of faults, whereby all the ground that lay to the north-west has been depressed below the Midland Valley. How far the original Silurian uplands went northwards, and especially whether they were ever continuous with those of the Highlands, before the formation of the boundary faults and the depression of the Midland Valley, we cannot tell, but their fragmentary condition must be taken into account in reasoning out the history of their valleys, and especially of those remarkable cases where the streams flow completely across them.

I have already mentioned that the position of a watershed may be of much interest and importance in any inquiry into the history of the surface of the region which it traverses. The watershed of the Southern Uplands supplies an excellent

example of this relation. Running from the mouth of Loch Ryan in a sinuous north-easterly direction, it keeps near the northern limit of the region till, reaching the basin of the Nith, it quits the hills altogether, descends into the lowlands of Ayrshire, and after circling round the head-waters of the Nith, strikes south-eastward across half the breadth of the uplands. It next turns abruptly northward and eastward, between the basins of the Clyde, Tweed, and Annan, and then through the moors that surround the sources of the Ettrick, Teviot, and Jed, into the Cheviot Hills. Throughout this region, as in the Highlands, the longest slope is to the east, where the Tweed bears the drainage of that side into the sea. Although the rocks have a persistent north-east and south-west strike, and though this trend is apparent in the bands of more rugged hills that mark the outcrop of hard grits and greywackes, nevertheless geological structure has been less effective in determining lines of ridge and valley than in the Highlands. Obviously the watershed wanders to and fro across the region, without reference to any dominant axis produced by the plication and upheaval of the Silurian rocks. It must have been traced out at a time when the structure of these rocks did not influence the surface features: in other words, when the Silurian strata were buried under younger formations. Thus, even before we begin to consider the erosion of the system of valleys, the mere position of the watershed suggests enormous denudation of the surface and the removal of an overlying cake of younger deposits. It thus confirms the conclusion to be drawn from the position of what remains of the Old Red Sandstone along the borders of the hills.

In commencing the examination of the valleys that wind through those high grounds, we may with advantage take notice of the local names which have been given to the different types of valley in the south of Scotland. And here allusion may be made to the fact that the topographical names in the two sections of the Southern Uplands bear witness to the

strong influence which the superficial configuration of the ground has had upon the distribution of the different races of its inhabitants. To the south-west of the Nith, where the Celtic population remained longest unabsorbed by the Teutonic element, the names of streams and hills are still in great measure Gaelic; while to the north-east of that river, Saxon names are predominant. In the former region, for instance, some of the wider valleys are known by the Highland name of "glen," as in Glen Afton and Glen App; in the eastern district such valleys are called "dales," as Clydesdale, Tweeddale, Teviotdale, Liddesdale, Eskdale, Nithsdale, Annandale, Moffatdale. Less important valleys are known by the name of their streams, as in Ale Water, Gala Water: each of these names being used not merely of the stream, but of the little dale watered by it, and of the people dwelling by its banks. In the ballad of *Jamie Telfer*, "auld Buccleuch" bids his men

> "Gar warn the water, braid and wide,
> Gar warn it sune and hastilie."

And in enumerating the followers that would join him he takes for granted that with Wat o' Harden and his sons "will Borthwick Water ride." A "cleugh" is a still narrower and steeper-sided valley, chiefly to be found in the higher parts of the uplands. A "hope" is the upper, closed end of such a narrow valley, encircled with smooth green slopes.

In no part of Scotland is the relation of the valleys to the streams that flow in them so strikingly shown as in these Southern Uplands. The uniformity of geological structure and monotony of feature allow us to trace out the valley systems without the conflicting impressions that great ruggedness and variety of surface can hardly fail to produce. There is a singularly apt proportion maintained between the size of each stream and that of its valley. The drainage-lines wind across the table-land with all the sinuosity and tree-like ramification of channels cut by running water. Seen from a height,

indeed, the whole region looks like a model of the drainage-system of a country.

If we try to apply the classification of longitudinal and transverse valleys to those of the Southern Uplands, we find a still larger number of exceptional cases, where there is obviously no real relation between any central axis of upheaval and the lines adopted by the drainage. The largest number of valleys may be called transverse. Beginning at the east end, we find the valleys of the Monynut, Whiteadder, and Leader among the Lammermuir Hills. Farther west are the Gala, Eddleston, and Lyne Waters, and beyond the wide basin of the Tweed lie the valleys of the Esk, Annan, Clyde, Nith, Dee, Doon, and Cree, with others of less note. As a rule, these streams rise close to the north-western edge of the table-land, and flow across to the low grounds on the south-east. The Whiteadder and Leader, for example, take their rise within about two miles from the northern base of the Lammermuirs, and run thence southward to join the Tweed. Of the Dee, also, some of the tributaries have their sources not three miles from the edge of the table-land on the north side, but nearly fifty miles from sea on the opposite side. There is no example of a river rising near the southern edge of the uplands and flowing across them to the north.

But not only do most of the large streams begin close to the north-western flank of the uplands; two of them, the Lyne Water and the River Nith, actually take their rise beyond the Silurian belt altogether, and flow completely across it. The Lyne has its source among the Pentland Hills, from which it descends into a broad plain between Linton and Romanno. It then strikes right into the Silurian hills, and joins the Tweed. The Nith takes a still more singular course. Its springs well out of the north flank of the uplands, and the infant river descends northwards, as if to make its way into the Firth of Clyde. But wheeling abruptly round, it plunges into the uplands again and flows right across them into the

Solway. These heights cannot have existed as a continuous range of high grounds when the valley of the Nith began to be traced. We know, indeed, from the evidence of the Sanquhar coal-field (*ante*, p. 313) that the Silurian rocks in that part of the country must have been buried under Carboniferous strata, and it was doubtless on a wide Carboniferous platform, stretching far over the buried Silurian region on the one side, and over the Midland plain on the other, that the infant Nith chose its pathway across what is now the site of a range of hills. Many geological changes have since taken place, but none of them have been potent enough to make the river loosen its grip of the channel which it originally took; at least, it has been able to resume that channel in spite of them.

Again, the Tweed and its tributaries wander across the edges of the sharply-tilted Silurian rocks in such a defiant manner as to indicate that these rocks could not have been exposed at the surface at the time when the streams began to flow; otherwise their strongly marked geological structure would have influenced the lines of valley. We have seen that the Upper Old Red Sandstone, though now confined to the lower parts of the basin of the Tweed, evidently at one time spread far and wide over the Silurian area, and we may infer that on a surface of that formation, exposed by upheaval, the drainage-lines were not improbably determined. While the erosion of the valleys was in progress, the general surface of the region was simultaneously lowered by sub-aërial waste. In the end, cutting down through the cover of Old Red Sandstone, the streams dug into the Silurian strata underneath, but these strata could no longer influence the direction of the valleys, which accordingly continued to wind about in them with the curves that had been determined by the original inequalities in the overlying mantle of younger deposits.

Longitudinal valleys, whose trend really coincides with that of the Silurian strata on which they lie, are hardly to be found

in any part of the Southern Uplands. The most conspicuous example is Glen App in Wigtownshire.[1] The Stinchar and Muck Waters likewise run in a general sense parallel with the strike of the rocks. The course of the former stream runs for miles parallel to but not coincident with a large fault, which may have given rise to some long hollow at the surface, whereof the river at first took advantage. But instead of rigidly following that line, the water-course now lies some way on the north side of it, and actually cuts across it twice.

It thus appears that the valley system of the Southern Uplands, like that of the Highlands, bears everywhere the impress of its origin, not in subterranean movements, but in superficial erosion. We can only speculate vaguely as to the general form of the ground when this erosion began. Although merely a fragment of the table-land is left, enough of it remains to show through how many great geological revolutions the region has passed. We may conceive that when the present drainage-lines began to be traced, a large part of the cover of Permian, Carboniferous, and Old Red Sandstone strata still lay thickly upon the Silurian rocks underneath. Probably even from the outset the table-land, as defined in its area and height by subterranean upheaval, had a short steep face towards the north-west, and a longer and gentler slope in the opposite direction. On such a south-easterly declivity the drainage would arrange itself into water-courses which would, on the whole, take a south-easterly course. But in the north-eastern part of the region, where the cover of younger formations was probably thickest and remained longest, the slope appears to have been rather towards the north-east and east. Once chosen, the water-channels would be deepened and widened, and as long as the land remained above the sea, would sink farther into it, thus establishing the present network of valleys.

[1] This valley, however, probably owes more to the influence of one of the great boundary faults which appears to be prolonged into it, than to the strike of the rocks.

It is interesting to note that, in some instances, the existing valleys coincide more or less markedly with valleys that were excavated in ancient geological times, and were subsequently buried under piles of debris. The depression that now forms the vale of Lauderdale, for example, is at least as old as the Upper Old Red Sandstone period. Even at that early time, it had been worn out of the Silurian table-land. Masses of gravel and sand, washed down from the slopes on either hand, gathered on its floor. A little volcano, contemporaneous, perhaps, with the larger outbursts of the Eildon Hills and the Merse of Berwickshire, broke out at its upper end, but was at last buried under the accumulating heaps of detritus, which in the end filled up the valley and spread over the surrounding hills. In the course of later geological revolutions, this region has once more been upraised, denudation has been resumed, the Old Red Sandstone has been in great measure stripped off the hills, and at last the long hollow once more exposed to the air has again become a valley that gathers the drainage of the surrounding high grounds. The history of Lauderdale is well illustrated by another depression of the same age, from which the sediment that filled it has not been removed. This tract stretches between Dunbar and Greenlaw, completely across the present chain of the Lammermuirs. The red conglomerate and sandstone still choke it up, and it remains a buried valley of the age of the Upper Old Red Sandstone.

Nithsdale existed, at least in part, as far back as the early portion of the Carboniferous period, for strata of Carboniferous Limestone age lie in it. But it was buried under Coal-measures during the later stages of the same period. In Permian times, however, it had again been partially re-excavated, though probably not quite along the old line. Permian breccias, with here and there the relics of Permian volcanoes, lie at the bottom of the valley from Dumfries nearly up as far as Sanquhar.

Annandale is another valley which had already, in the Permian period, been excavated as deep as it is now, as is proved by the cake of breccia on its floor. But, like the others, it was no doubt entombed under Permian or younger deposits. Far to the south-west, the depression filled by the waters of Loch Ryan and Luce Bay seems to be another transverse land-valley, once stretching away to the north-west, and as old as the Carboniferous period, for both Carboniferous and Permian strata line its western side. In all these examples of the survival of ancient valleys, which have been adopted into the present drainage-system of the country, there is clear evidence that the hollows were deeply buried under younger formations, which thus preserved them, and their subsequent exposure by denudation belongs to a comparatively recent geological period. From the evidence of the Tertiary dykes we know that, in some cases at least, the valleys were still buried even in older Tertiary time (pp. 166, 339). Hence the continued existence of a very ancient valley furnishes, when fully considered, no real argument against the view that the rapidity of denudation is such as to show that the present topography of the country cannot be of high geological antiquity.

It is unnecessary to enter into further details of the local topographical results of sub-aërial waste among the Southern Uplands; for, making allowance for the different materials operated on, these results do not differ in any essential feature from those already described from the Highlands. Numerous examples, for instance, might be cited of the recession of two glens towards each other, and of the final result of this degradation in the formation of a valley or pass across the intervening ridge. Some of the best illustrations of this kind of land-sculpture may be seen in the deep valleys about the sources of the Moffat, Megget, and Talla Waters. Moffatdale itself is connected by such a pass with the Vale of Yarrow. In the same region may be seen the few true corries of the north-eastern half of the uplands. It is in the south-western

part of the region, however, that these features are best exhibited. Narrow crests, high cols, and worn-down passes abound in the mountainous ground between Dalmellington and Wigtown.

Nor need more than a passing allusion be made to the influence of the varying character of the rock upon the aspect of the scenery. I have already noticed the more rugged outlines of Galloway and Carrick, as contrasted with the smooth monotony of the Peeblesshire and Lammermuir Hills, and have referred this difference to the greater variety and more unequal texture of the rocks of the Highland-like tracts, combined with a greater rainfall and consequent intenser erosion on the western than on the eastern side of the country. Nevertheless, as has been above insisted on, it is the wonderful uniformity of scenery throughout the uplands which is on the whole their distinguishing characteristic, and which is so faithful a reflex of the remarkable persistence of the same geological structure. Any notable change in the structure and durability of the rocks is sure to make itself apparent in the form of the ground. Thus the bands of hard grit and fine conglomerate, which run in continuous parallel bands in a south-west and north-east direction along the uplands, show themselves in more rugged strips of hill, on the sides and crests of which the naked rock more frequently protrudes in crags and scars. Such are the heights that range south-westwards from Queensberry Hill across Nithsdale into Galloway. The shales, on the other hand, crumble down into finer debris, and consequently produce long smooth declivities, such as the green slopes of the Lowther Hills.

The igneous rocks likewise give rise to local peculiarities of configuration. Although the Silurian formations of these uplands are so extensively underlain with a volcanic platform of Lower Silurian age, this platform has been deeply buried under the subsequent sedimentary deposits, and can only now be seen on the crests of the deeper anticlines which bring it up

to the surface. For the most part, these plications allow no more of it to appear than suffices to attest its position and persistence. As above stated, it is displayed only at two places over a wide enough extent to permit its structure and composition to be adequately studied. One of these lies in the south of the district of Carrick in Ayrshire, where the volcanic rocks on the north and south sides of the River Stinchar spread over an area of about 25 square miles. The other is in Nithsdale, close to Sanquhar, where they have been uncovered for not quite one square mile. But in neither of these two districts do they contribute any distinctive peculiarity to the scenery. Their most prominent feature is the great cone of agglomerates and breccias which forms Knockdolian Hill in the valley of the Stinchar, a little to the east of Ballantrae.

But though the contemporaneous igneous rocks associated with the Silurian sedimentary formations do not seriously affect the landscapes of the Southern Uplands, it is otherwise with the intrusive series which has been injected subsequently into these formations. Thus, the granite hills of Galloway, though never peaked, form high smooth domes or bosses which display their lines of low grey cliff and craggy slope, whence many a block has been scattered over the lower grounds. The detached bosses of felsite, or the necks of ancient Carboniferous volcanoes, stand out as prominent cones, while the sheets of Carboniferous lava range in lines of terraced escarpment. The best locality for tracing the influence of such igneous rocks upon landscape is in the tract of Border country between Birrenswark and the Merse of Berwickshire. Among the more prominent eminences of this kind are Tinnis Hill, and Watch Hill in Liddesdale, Pike Fell (and part of Arkleton Fell) in Ewesdale, Greatmoor, Maiden Paps, Scawd Law, Leap Hill, and Windburgh Fell at the head of the Slitrig valley, Bonchester Hill, Rubers Law, Black Law, Dunian Hill, Lanton Hill, Minto Crags, Peniel Heugh, the Eildon Hills, the numerous little

hills between Maxton on the Tweed and the foot of Lauderdale, and the long line of craggy heights that stretch by Smailholm and Stitchill to Greenlaw.

In connection with the eruptive rocks of the region, reference has been made to the basalt-dykes which run across the uplands from south-east to north-west. Though they do not form any striking feature in the topography, their persistent course across hill and valley throws much light on the history of the denudation of the high grounds of the south of Scotland. The evidence furnished by them is precisely similar to that

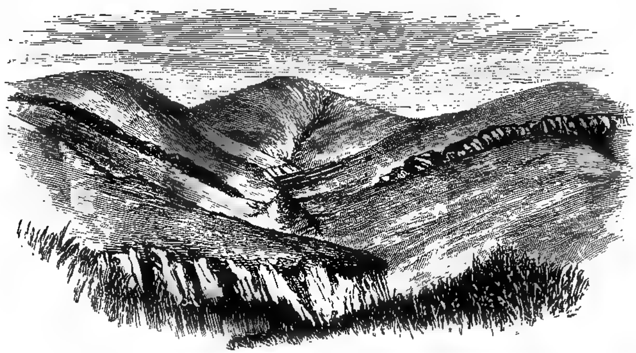

FIG. 90.—Tertiary dyke crossing the Glengap Burn, near Moffat, and showing the excavation of the valley since older Tertiary time.

which has already been adduced from the Highlands. The Tertiary age of these dykes may be considered to be sufficiently established. They cross some of the widest and deepest valleys among the Silurian hills, and they therefore prove that these valleys must have been eroded since older Tertiary time. The case of Annandale is particularly interesting. I have referred to that valley as being as old as the Permian period. That it was filled up with Permian deposits, and remained so in early Tertiary time, is shown by the great dyke which crosses it near Moffat. Since then the valley has been cleared out, most of the Permian breccia and sand-

stone has been removed, and the dyke has been laid bare along the slopes and bottom. The dyke forms no prominent surface feature at Moffat, but a few miles to the south-east, where it crosses the Glengap Burn, near the Wamphray Water, it runs as a prominent rib down each side of the valley (Fig. 90). A more striking proof of the excavation of the valley since the time of the dyke could not be desired. Other dykes cross the valley of the Clyde below Crawford, so that the erosion of that hollow also has been effected since early Tertiary time.

CHAPTER XIV

THE ANCIENT GLACIERS OF THE SOUTHERN UPLANDS

As the rocks of the southern district of Scotland are on the whole less durable than those of the Highlands, they have not preserved quite so faithfully or universally the impress left upon them by the ice-sheets of the Glacial Period. That they have been intensely glaciated, however, will be recognised by any one who seeks for proofs of ice-work. In spite of the thick mantle of boulder-clay that covers so much of the valleys and lower hill-slopes, and in spite also of the tendency of so many of the rocks to decay and to be concealed beneath a coating of turf or peat, abundant polished and striated rocks may be found in every district from the headlands of Wigtownshire to those of St. Abb's Head. In some parts of Galloway, indeed, the *roches moutonnées* are hardly less perfect and conspicuous than in most of the Highlands.

From the direction of the striæ, it is evident that the Southern Uplands formed another centre of dispersion for the southern part of the Scottish ice-sheet.[1] A vast mass of ice flowed northwards into the plain of Ayrshire, where, joining the stream that was descending from the Highlands, it bent round to the west and went southwards down the Firth of

[1] To speak more accurately, there were several distinct centres of movement of the ice that lay on these uplands, as will be evident from Plate IV. But the southern ice-field may be regarded as one vast sheet that moved outwards and downwards into the low grounds on all sides.

Clyde. Still thicker and more extensive was the great ice-field that crept off the southern side of Galloway into the Solway Firth and the Irish Sea, both of which, at the height of the Ice Age, were filled with ice. Across the eastern part of the Uplands, the pressure of the deep and wide *mer de glace*, which descended from the Highlands into the Lowland valley, seems to have driven the southern ice eastward, and the united stream then turned away to the south along what is now the bed of the North Sea. Proofs of these movements are furnished not only by the direction of the striæ, but by the scattered erratics which have been strewn over the ground. The evidence for them is given in summary form on the Map of the Glaciation of Scotland accompanying this volume (Plate IV.).

The boulder-clay tells perhaps even more markedly in the scenery of the Southern Uplands than in the Highlands. It has accumulated to a great thickness in the valleys, where it forms a kind of sloping floor or platform, extending from the base of the declivity on either side, and trenched by the stream which, in winding across it, has exposed great scars of it in the banks. It is more especially banked up on the lee sides of the hills, while the opposite sides, against which the full pressure of the ice came, are comparatively bare. In Peebles-shire and Selkirkshire, where the march of the ice-sheet was from the west, the west sides of the valleys are thickly spread with boulder-clay, while on the east side the bare rock comes abundantly to the surface.

In these valleys, the boulder-clay has a twofold influence on the landscape, for it gives to their floor and to their lower slopes a smoothness which the bare rock would not have furnished, and, by presenting itself in bold bare scars and steep grassy slopes along the course of each stream, it redeems the scenery from the featurelessness which would otherwise characterise it.

But the most prominent part taken by the boulder-clay in the configuration of the southern counties of Scotland, is to be seen

in the south of Galloway. This remarkable deposit, which everywhere shows a tendency to arrange itself in parallel mounds, has there carried out this tendency on a great scale, and with a distinctness seldom elsewhere reached in Scotland. Over those parts of the ground which are free of drift, ice-worn bosses of bare rock project nakedly out of the moor and boulders around them. In marked contrast to them are the long mounds and ridges or "drums" of boulder-clay, with their smooth green grassy surfaces. These ridges are not mere fragments of a once continuous deposit cut into shape by denudation. That their peculiar and characteristic forms are original is made quite evident by their independence of the water-courses and by the parallelism of their long axes with the direction of the ice-striæ on the surrounding rocks. They undoubtedly point to some arrangement of the detritus under the ice-sheet, in the same line as that in which the ice itself was moving. The nature and history of boulder-clay will be further alluded to in Chapter XVII.

The boulders left by the ice-sheet form a notable feature in the south-western half of the uplands, though they are comparatively inconspicuous in the north-eastern part. The granite hills of Galloway have furnished millions of blocks that have been scattered all over the country, from heights of 2000 feet down to the sea-level and below it. A remarkable stream of such boulders, for example, may be traced from the source of the Girvan Water, down the course of that stream to its mouth. They are perched high on the hill-tops on either side, at a level of 800 or 900 feet above the valley-bottom, so that the ice must have been at least 800 or 900 feet thick in the lower part of the Girvan valley. Some of the blocks, even many miles away from their source, are of great size. One of them on the north side of the valley, some three miles from the sea, known as the Baron's Stone of Killochan, measures about 480 cubic feet, and weighs somewhere about 37 tons[1] (Fig. 91). The southern

[1] See my *Geological Sketches at Home and Abroad*, p. 46.

parts of Galloway are strewn with granite boulders, carried down by the ice which descended from the great cauldron between the heights of the Kells and Merrick. Some of these blocks make conspicuous landmarks or have received special names. Thus on the farm of Blairbuie, in the parish of Glasserton, Wigtownshire, a rudely egg-shaped boulder of grey granite rests on gravel at a height of 125 feet above the sea. It contains about 200 cubic feet of stone, and must weigh some 15 tons. It is known locally as the "Wren's Egg." This block has been

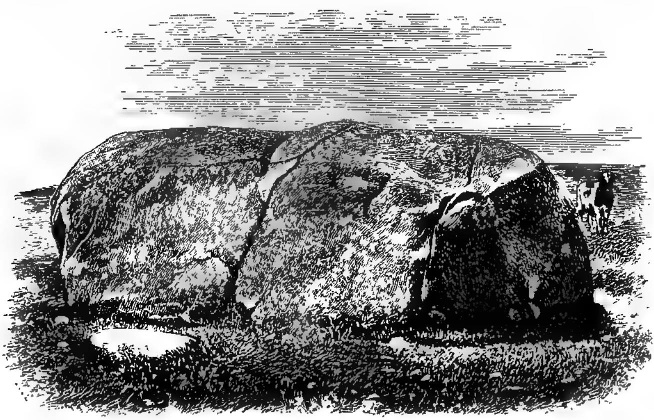

FIG. 91.—The Baron's Stone of Killochan. A granite boulder in the valley of the Girvan.

transported about twenty or thirty miles from Cairnsmore of Fleet or from the hills around Loch Dee.

Another relic of the ice-sheets is to be seen in the curious mounds and ridges of sand and gravel known as "Kames" or "Eskers." Some remarkable examples of these features occur on the southern side of the uplands, between Greenlaw and Duns in Berwickshire. But as the best display of them is to be seen in the Midland Valley, the description of them will be given in a later chapter.

That valley-glaciers continued in the "coombs" and "hopes" of the Southern Uplands, as they did in the corries and glens of

the Highlands, after the ice-sheet had crept backward from the lower grounds, is admirably revealed by many a group of moraines. In the eastern half of the region, the most marked of these traces occur at the heads of the deep narrow valleys that run up into the mass of high ground between the upper part of Tweeddale and the sources of the Moffat and Yarrow. In that lonely tract, the moraine heaps, with their blocks lying scattered about on them, are as fresh in their forms as if the glaciers had vanished only a few years ago. In ascending the defile of the Talla, above the picturesque linns, we come upon mound after mound, sometimes rising 50 or 60 feet above the stream which has cut its way through them. They run across the glen in curves that point down the valley, each of which marks a pause made by the glacier as it shrank, step by step, up into the narrowing snowfield at the head of the glen. Beyond the top of the Talla valley two deep semicircular recesses have been scooped out of the sides of the mountains (Fig. 92). One of these, that of the Midlaw Burn, is accurately described in Wordsworth's picture of a similar corry in the Cumbrian Chain.

> "A little lowly vale,
> A lowly vale, and yet uplifted high,
> Among the mountains;
> Urn-like it was in shape, deep as an urn,
> With rocks encompassed, save that to the south
> Was one small opening, where a heath-clad ridge
> Supplied a boundary, less abrupt and close."

A level meadow occupies its bottom, and the "heath-clad ridges" which close it on the south are successive moraines—huge piles of rubbish, cumbered with massive angular blocks of greywacke. Over the site of the meadow there evidently lay at no very remote date a lake, that was ponded back by the moraine heaps and has been gradually drained as the outflow of the water has cut down the enclosing barrier.

The other recess is that of Loch Skene, which is held in on

the north and west sides by steep and, in part, precipitous slopes of craggy rock, on the east and south by moraine mounds. I shall not soon forget the surprise with which, after climbing with my old friend and colleague in the Geological Survey, Professor John Young, the ravine of the Grey Mare's Tail, and wandering through the heaps of glacier rubbish that lie along the valley above the linns, I saw from the last moraine mound the blue waters of Loch Skene asleep in the shadow of the crags. Everything around told of the old glaciers;—mound after mound stretching in crescent-shape across the valley, and coming down in irregular piles from the Midlaw corry on the

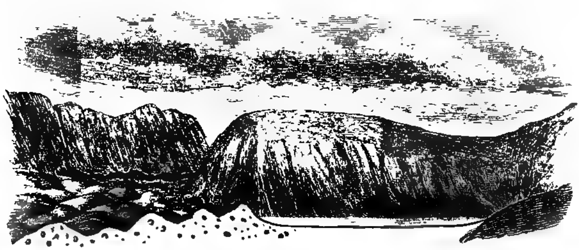

FIG. 92.—Sectional view of Loch Skene, Dumfriesshire. The valley to the left is that of the Midlaw Burn.

left; huge masses of rock still poised on the summits of the ridges where they had been tumbled by the ice that bore them from the dark cliffs at the head of the coomb; and then the still, sombre lake itself, so impressively the result of the damming back of the water by the bars of detritus thrown across the glen.[1] The stream that issues from the lake is busy cutting down the moraine-barrier, and every rain-storm helps to sweep detritus from the surrounding crags and slopes into the lake.

[1] Dr. Robert Chambers published an allusion to the moraines of Loch Skene in the *Edin. New Phil. Journ.* New Series (1855), vol. ii. p. 184. They were briefly described in my memoir on the "Glacial Drift of Scotland" (*Trans. Geol. Soc. Glasgow*, vol. i. p. 160, 1863). They were carefully mapped in detail by Dr. Young, and the chief results of his investigation of them are given in his paper, *Quart. Journ. Geol. Soc.* for 1864.

Eventually Loch Skene will be drained, and its site will become a grassy plain like that of the Midlaw Burn above it (Fig. 93).

But the mass of high ground between Nithsdale and St. Patrick's Channel was the chief seat of glaciers in the south of Scotland. Indeed the proofs of intense glacial action are hardly less striking there than in the mountainous parts of the Highlands. Most of the innumerable lakes of the district lie either in hollows among moraine mounds, or in ice-worn basins scooped out of the rock. Thus, between the foot of the range of the Merrick Hills and the Bay of Luce, the ground is one wide expanse of moor, roughened with thousands of heaps of glacier detritus, and dotted with scores of lakes enclosed among these rubbish mounds. The mass of ice which came down from the high grounds and moved westward and southward must have been very great. Between the head of the Stinchar and Wigtown Bay, fully five-and-twenty miles broad, it moved towards the south with resistless force, for all the hills and hummocks of rock in its way are found to have been ground down, polished, and striated by it, while the surface of the country is strewn with mounds, ridges, and heaps of clay, gravel, and boulders. It gives us a lively idea of the continued severity of the climate to reflect that so limited a group of hills, the summits of which are little more than 1800 or 2000 feet above the sea, should yet have nourished massive glaciers that carried boulders of granite away north, south, east, and west, and dropped them over the plains, even far into the heart of England.

As an example of the extreme glaciation of this region, I may refer to the valley of Loch Doon. A rugged cauldron-like amphitheatre, some four or five miles wide, lies there enclosed between the Kells range on the east, and the Merrick on the west. The bottom of this extraordinary hollow is roughened with prominences which, were they not dwarfed by the lofty summits around them, would be looked on as noteworthy hills. It is dark with peat, shaggy with heather, and dotted with

numerous tarns and lochs. Its collected drainage finds an exit by a narrow valley at the northern end, and it is there that Loch Doon lies. The lake itself, with its head fairly within the amphitheatre, stretches northward for six miles, with an average breadth of rather less than half a mile.

Down this valley, at the height of the Glacial Period, there must have been a vast pressure of moving ice. The wide cauldron, up to the brim of its surrounding mountains, was choked with ice, and consequently the most marked evidence of glacial erosion may be seen in the hollow by which the ice escaped. The ledges of rock that project out of Loch Doon are as smooth and polished as a well-worn pavement, and are covered with long ruts and grooves that run parallel with the direction of the valley. Near the head of the loch some of these projections, consisting of hard, dark greywacke, traversed with granite veins, have been shorn as smooth as if a committee of geologists had determined to lay open to the best advantage a complete section of the junction of the two rocks. The rocky islets, similarly polished and striated, show the smooth, convex, flowing outlines so characteristic of *roches moutonnées.* One of them, indeed, has been called by the people of the district the "whale's back." Wherever the rock along the side of the valley has been recently bared, it retains the ice-worn surface singularly well preserved. Loch Doon is a true rock-basin. At its foot, the barrier of rock which keeps back the water is smoothed and striated, the direction of the markings proving that the ice has come up out of the lake. Not only so. For a hundred feet or more above the level of the water, the rocks which rise above the end of the lake are similarly worn. There can be no doubt, I think, that the ice which filled the hollow of Loch Doon went up the slope at its northern end, and so passed down into the valley beyond. The deep gorge of Glen Ness, by which the river escapes, seems to be partly the work of the Glacial Period, but much deepened since then by the roaring torrent which fills the narrow chasm from side to

side. Besides its polished and striated rocks that tell of the

Fig. 93.—Loch Skene, Dumfriesshire. A lake ponded back by moraine mounds which are being cut down by the escaping stream.

maximum glaciation of the great ice-sheet, the Loch Doon

valley shows abundant moraine rubbish of the time when the ice-sheet had shrunk into independent valley-glaciers. Granite boulders, everywhere especially numerous, are sometimes thickly clustered in patches along the margin of the loch, or heaped on its islets. Some of the islets, indeed, look like the tops of moraine mounds appearing above the water. In short, there is no locality in the south of Scotland where the existence and effects of ancient glaciers can be more impressively seen, and none where the glaciation of a rock-encircled lake-basin is more clearly displayed.

Since the last remnants of the great snow-fields and glaciers melted away from the uplands of the south of Scotland, there has been a good deal of minor change in the general features of the district. The crags and cliffs where the naked rock comes out into the light have had their smooth ice-worn surfaces splintered by frost and roughened by air and rain, and their ruins are seen below them in screes of loose rubbish. Many a runnel has deepened its first channel into a gully that runs as a narrow gash down the otherwise smooth hillside. The brooks and rivers too have been busy in eating away their banks and lowering their beds. Some of the most picturesque ravines, such as that of the Crichhope Linn in Nithsdale, have been cut by running water since the Glacial Period, and older, or what are known as "pre-glacial," stream-courses are now filled up with boulder-clay.[1] The lower terraces and alluvial haughs that flank the margins of the larger streams have likewise been made since then. Into the changes due to vegetation —the growth and disappearance of forests, and the formation of peat-moss—I do not here enter, reserving until a following chapter a brief reference to the nature and proof of such changes over the whole country.

[1] An interesting example of this succession of events in the case of the Water of Gregg, South Ayrshire, will be found in Chapter XVII.

PART IV

THE MIDLAND VALLEY

CHAPTER XV

PHYSICAL FEATURES AND GEOLOGICAL STRUCTURE

Between the southern flank of the Highlands and the northern edge of the Uplands of the pastoral counties lies that wide hilly lowland which, for want of a better name, I have been accustomed to call the Midland Valley. It is only in the broad sense, as a band of lower ground between two ranges of high land, that it can be spoken of as a valley; nor can a district so plentifully dotted with hills, and even traversed by long chains of heights, be in strictness termed a plain. Looked at from the geological point of view, however, this belt of low-land country occupies a broad depression defined by parallel dislocations, and bounded on either side by hills which consist of older rocks. It may thus be regarded as a valley, owing its form and direction to geological structure.[1]

Between the other two great belts of Scotland and this Central Lowland there is the fundamental distinction that they owe their prominence to having been upraised relatively to the surrounding areas, while the intervening tract has undergone subsidence. In the Highlands and Southern Uplands the oldest rocks in the geological structure of Scotland are exposed. In the intervening lowland, younger formations which once spread out over the hilly regions on either side, but have since been almost wholly removed thence, have been preserved by

[1] See Section No. 4 on the Geological Map, where the general geological structure of the Midland Valley is shown.

having been let down into the hollow. The results of denudation accordingly present themselves here in another aspect.

In order to follow intelligently the progress of evolution in the development of the scenery of Central Scotland, it is needful to attend with some care to the character and thickness of the various geological formations that occupy the area, to the manner in which these are now arranged with regard to each other, and to the probable conditions in which they were successively deposited.

Reverting for a moment to the geological structure of the Highlands and Southern Uplands, the reader will remember that the great terrestrial movements which began to affect these regions before the close of the Silurian period, threw the deep masses of older Palæozoic sediments into vast plications, crumpled them in endless minute puckerings, ruptured them with innumerable faults, pushed them over each other, tore up vast masses of the underlying platform of Archæan gneiss, and so crushed these and the Palæozoic strata as to give rise to a newer series of gneisses and schists. He will recollect also that these prodigious disturbances in the crust of the earth were directed in a general sense from south-east to north-west, that consequently the trend of the dislocations and of the axes of plication runs from south-west to north-east; and that it is this structure which has determined the prevalent north-easterly course of the great belts of country in Scotland. To these subterranean movements, and to others subsequently continued in the same average direction, the Midland Valley owes its north-easterly trend, and the straight parallel sides which bound it.

If we could clear out all the younger Palæozoic deposits that now fill up the broad central depression of Scotland, we should probably find the Silurian rocks of the Southern Uplands continued in endless anticlinal and synclinal folds towards the Highland border, becoming gradually more metamorphosed in

that direction, and eventually joining the grits, conglomerates, slates, radiolarian cherts, and diabases along the edge of the Highlands from Arran by Callander and Aberfoyle, into Kincardineshire (p. 130). But though continuous underneath, they may never have formed a continuous tract of hilly ground at the surface. On the contrary, there is good reason to believe that the very movements which plicated, fractured, and upheaved the areas to the north and south, depressed this central region. And if this be true, then it would follow that the Midland Valley had its general position determined as far back as Palæozoic time.

The oldest strata anywhere exposed in the centre of Scotland, between the margin of the Highlands and that of the Southern Uplands, belong to the Upper Silurian period. They are only seen in two or three limited areas, where they come to the surface from under the vast pile of sedimentary accumulations which elsewhere overlies them. In Lanarkshire, and the southern part of the Pentland Hills, where they attain a thickness of probably not less than 3500 feet, their base is nowhere seen, so that we do not know what their total depth may be. From their gentle inclination over much of their extent, and from their gradual passage upward into the Old Red Sandstone, they were evidently, across certain wide districts, comparatively little affected by the great disturbances that had convulsed the previously deposited portions of the Silurian system. But their occasional crumpling and plication show that these disturbances had not finally ceased.

Next comes the Lower Old Red Sandstone—a pile of conglomerates, sandstones, shales, and volcanic rocks, attaining a total thickness in Kincardineshire of more than 20,000 feet. This vast mass of sedimentary and igneous material appears to have accumulated in a lake or inland sea that spread over the Midland Valley, and probably stretched south-westward into the north of Ireland, and north-eastward across what is

now the floor of the North Sea. This ancient long-vanished sheet of water, which, for convenience of reference, I have called "Lake Caledonia," not improbably owed its origin to the subterranean movements just referred to. It was an area of depression, bounded on the north-west and south-east by tracts that were undergoing uplift. The energy of the underground forces is well shown in the thick masses of lava and volcanic ashes that were discharged from numerous volcanoes along the floor of the lake, and now form important ranges of hills. In the Pentland and Ochil Hills these accumulations exceed 6000 feet in thickness.[1]

Originally, of course, the Lower Old Red Sandstone covered the whole of the Midland Valley, and, as we have seen, extended also into the Highlands on one side and over more or less of the Southern Uplands on the other (*ante*, pp. 157, 312, and Figs. 46, 47). But in the course of long ages of geological change, its superficial area has been greatly restricted, partly from its having been stripped off by denudation from the hilly ground on either hand, but chiefly owing to the spread of younger formations above it. Yet it still occupies wide belts of country, and forms the highest and most picturesque ground in Central Scotland. It runs along the northern side of the Lowlands, from the coast of Kincardineshire and Forfarshire south-westward across the island to the Firth of Clyde, where it is well seen in Arran. Along this northern belt, its associated volcanic sheets form the long chain of the Sidlaw and Ochil Hills.

There is no corresponding continuous broad belt of Lower Old Red Sandstone along the southern borders of the Midland Valley. The same kind of rocks, however, appear there in a tract of moory heights stretching from the Pentland Hills, which consist chiefly of lavas and volcanic tuffs, to the Ayrshire

[1] For an account of the deposits of "Lake Caledonia," and their associated volcanic accumulations, see my *Ancient Volcanoes of Britain*, chaps. xvi.-xx.

coal-field. The well-known ravines and Falls of the Clyde have been excavated in the sandstones of this series.

A long lapse of time passed away between the deposition of the Lower and that of the Upper Old Red Sandstone. The ancient lake, which had been undergoing depression until thousands of feet of sediment were piled up on its floor, appears to have been effaced, its hardened gravels, sands, and lava-sheets were upraised and denuded, and on their upturned and wasted edges the conglomerates and breccias and the red and yellow sandstones of the upper division were laid down. These younger strata occupy a comparatively unimportant place in the geology of the region. A narrow strip of them follows the lower division for some way along the south flank of the Ochils, until overlapped by Carboniferous strata. More important masses of conglomerate and red sandstone, to which reference was made in Chapter XIII., appear on the south side, rising into conspicuous eminences among the Lammermuir and Pentland Hills, and appearing at intervals westward into Lanarkshire, and southwards to the English border.

The next system in ascending series—the Carboniferous—covers by far the larger part of the Midland Valley. From St. Andrews Bay and the mouth of the Firth of Forth it stretches across the country to the Firth of Clyde, spreading over the whole intervening region except where, along the southern margin, the Old Red Sandstone rises from underneath it. The Carboniferous rocks consist chiefly of sandstones, with shales, coals, fireclays, limestones, and ironstones. But they include also an abundant series of contemporaneously erupted, as well as subsequently intruded, igneous rocks, to which reference will be made farther on. The total depth of Carboniferous strata cannot be less than 6000 feet. Like the Old Red Sandstone, these rocks bear testimony to deposition in shallow water; indeed, they abound in what were successive terrestrial surfaces. Consequently they prove that, during

their accumulation, there was a gradual subsidence of the centre of Scotland to the extent of at least 6000 feet. Deposition of sediment, however, kept pace with the downward movement, so that the water, instead of becoming profoundly deep, always remained shallow.

That the Carboniferous formations extended over the whole region of what is now the Midland Valley cannot be doubted. Not only so, but, as I have already remarked, they not improbably stretched over much of the Southern Uplands, and possibly even of the Highlands. These table-lands, had they not for ages been protected by some thick cover of younger rocks, would have been far more deeply eroded than they are.

Above the Coal-measures of Ayrshire lies a little basin of the next group of rocks in the geological series which are perhaps equivalents of the English Permian. They consist of bright brick-red sandstones, with an underlying zone of dark lavas and red volcanic tuffs. Similar rocks occur in scattered outliers in Nithsdale. To the same geological period with the presumably Permian volcanoes of the south-western district, ought, probably, to be referred some detached volcanic vents in the eastern part of the Midland Valley, such as Largo Law and Arthur's Seat.

Of probably later date are the red sandstones and marls which cover so wide a space in the southern half of the island of Arran, and of which the precise geological position was long a matter of dispute. The discovery of fossils belonging to the *Avicula contorta*-zone of the Rhætic group, which has been recently made by the Geological Survey, indicates, if it does not absolutely prove, the stratigraphical horizon of these red strata to be Triassic. Though apparently restricted to Arran, these strata no doubt at one time extended over a much wider area of the Midland Valley. While these pages are passing through the press a startling discovery by my colleagues in the Geological Survey, Messrs. B. N. Peach and W. Gunn, shows that not only the Trias but also the Lower Lias, and even

the Chalk, once stretched over the region of the Clyde. These observers have detected near Shiskin, on the south side of the String Road across the island, a large volcanic neck filled with agglomerate which, though composed mainly of igneous material, encloses masses of Rhætic and Lower Lias shales and of hard white limestone with Cretaceous *foraminifera*, etc. These relics of younger formations have evidently fallen into the vent from above. They prove that Secondary strata once extended over the south of Arran. So great, however, has been the subsequent denudation that all trace of these forma-

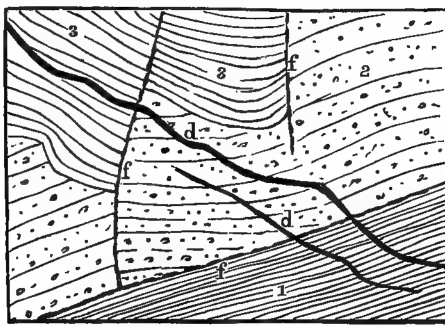

FIG. 94.—Map of Tertiary Dykes near Muirkirk, Ayrshire. 1, Silurian Rocks. 2, Lower Old Red Sandstone. 3, Carboniferous rocks. *ff*, Faults. *dd*, Dykes.

tions in place has been removed from the surface of the country, and but for the fortunate accident that fragments of them have been sealed up within a volcanic chimney, we might perhaps never have known for certain that they reached into the Midland Valley.

The volcanic centre alluded to no doubt belongs to the remarkable development of igneous rocks which form the youngest group in the geological structure of Arran, and have been referred to the same Tertiary volcanic period which witnessed the outbursts of Antrim and the Inner Hebrides. It is now demonstrable that these rocks in Arran are of later

date than the Chalk, and as there is no evidence elsewhere of Mesozoic volcanic action in Britain, the assignation of them to a Tertiary date is strongly confirmed.

Between the time of the Chalk and that of the Tertiary volcanic manifestations many geological changes may have transpired in the region of central Scotland of which no record now remains. We may be sure that denudation was unceasingly advancing over such tracts as were exposed above water. Possibly much of the cover of Secondary rocks was removed during that prolonged interval. Since the Tertiary volcanic period the amount of waste has likewise been prodigious. Impressive testimony to this degradation is furnished by the dykes of basalt and andesite, which belong to the same series already referred to as so prominent in the geological structure of the Highlands and Southern Uplands.[1] Scores of these dykes traverse the Midland Valley, in a general east and west or south-east and north-west direction (Fig. 94). There is a noticeable convergence among them, in the western part of the region, towards a point in the Firth of Clyde, between Dunoon and Greenock, as if that had been a focus from which the fissures radiated that were filled with the uprising lava. As in other parts of Scotland, the dykes do not play a prominent part among the surface-features of the Lowlands. Here and there, they may be noticed as ribs of harder rock, projecting in groups of low crags or detached blocks along the top of a ridge or the side of a hill, and marked by the brighter green of the grass which springs up on the fertile soil that results

[1] While the great system of north-west and south-east dykes, which can be followed across Scotland to the volcanic plateaux of the Inner Hebrides, may be regarded as of Tertiary age, there are, of course, numerous dykes throughout the Midland Valley which belong to older times of eruption. Some of them are connected with the widely diffused volcanic activity of the Carboniferous period. Others may be referred to the ejections of the Old Red Sandstone, while some (like those shown in Fig. 95) may be of Permian date. But in a discussion of their influence on scenery, the geological epoch of the intrusion of the dykes is a matter of comparatively small moment.

from their decay. Along the coast, dykes run sometimes as conspicuous walls, owing to the removal of softer strata from either side of them. Good examples of this feature are to be seen in Cumbrae and in Arran, and on the shores of the Firth of Forth (Fig. 95). In other cases, dykes decompose faster than the enclosing rocks, and are consequently hollowed out, leaving the gaping walls of the fissures which they once filled. Excellent illustrations of this phase are likewise to be seen along the shores of the Firth of Clyde, particularly on

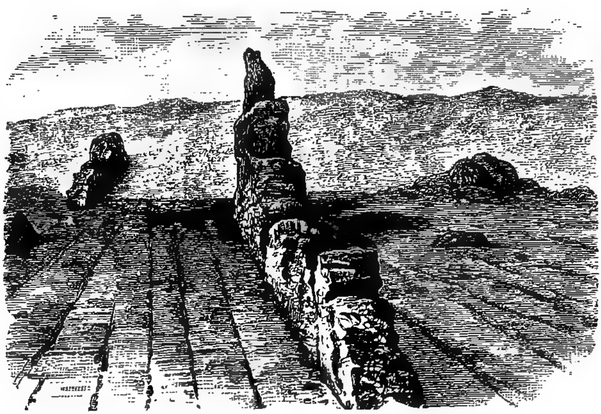

FIG. 95.—Basalt dykes traversing jointed volcanic tuff, Shore, Elie, Fife.

the east and south coast of Arran, likewise on the shore of the Firth of Forth, at St. Monans, in Fife.

But, as I have already stated, it is not so much for their influence on the topography as for the proofs which they furnish of the stupendous denudation of the country since older Tertiary time, that the dykes which may be regarded as of Tertiary age are of value and interest in our present inquiry. They teach in the Lowlands the same impressive lesson as in the Highlands and Southern Uplands (Fig. 90), proving that there also hundreds of feet of rock must have been worn away

from the general surface of the country since the fissures were filled with basalt.

The various superficial accumulations—boulder-clays, sands, and gravels, raised beaches, peat mosses, river alluvia, and the rest—which cover the greater part of the surface of the Midland Valley, will be more particularly described in reference to the scenic features with which they are connected.

Before concluding this enumeration of its rocks, I would say that it is the abundance of masses of igneous origin that gives to the geology of the broad Midland Valley its most distinctive feature. The Old Red Sandstone supplies the chain of the Sidlaw and Ochil Hills on the one side of the lowlands, and the Pentlands, Tinto, Corsincone, and the Brown Carrick Hills on the other. Not less important are the great sheets of lava and tuff which lie at the base of the Carboniferous system. These form the range of the Campsie and Kilpatrick Hills, with their noble escarpments facing across the Old Red Sandstone plain to the Highlands. Crossing the Clyde, they spread out in the uplands of Renfrewshire and North Ayrshire, where they rise into the terraced heights of Largs, and whence they run south-eastward in the high moorlands that extend to Loudon Hill. A similar series of lavas and tuffs, belonging to the same geological period, was referred to in Chapter XIII. as reappearing on the southern side of the Silurian uplands, in the escarpments of Birrenswark and Ewes Water, and extending into the Merse of Berwickshire through the range of heights crowned with Hume Castle. But besides occurring in widespread sheets, the volcanic rocks associated with the Carboniferous system appear in the basin of the Forth in abundant bosses, many of which mark the sites of actual volcanic orifices. The larger of these masses are disposed in groups of hills, as in the Garlton Hills and the range of heights between Bathgate and Linlithgow. But in the great majority of instances, the rocks form solitary crags and isolated eminences, such as Arthur's Seat, the rocks of Edinburgh, Stirling, and Dumbarton Castles, Binny Craig,

North Berwick Law, the Lomonds of Fife, Largo Law, the Bass Rock, and many more.

But for the existence of these igneous intercalations, the stratified formations of the Lowlands would have formed wide undulating plains, mounting here and there into long featureless ridges. It is the andesites, dolerites, basalts, tuffs, and other igneous rocks which, rising up into bold hills, have relieved the uniformity of the surface, and have given rise to much of what we recognise as distinctive of the scenery of the Central

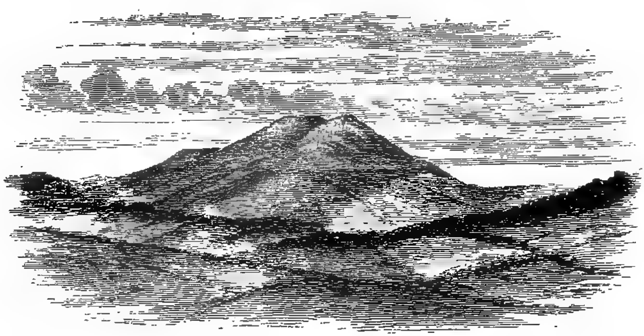

FIG. 96.—Largo Law, Fife. A volcanic neck, probably of Permian age (see Fig. 102).

Lowlands. It will be seen that the greater prominence of these materials is a fresh and impressive proof of enormous denudation.

So much, then, for the various rocks out of which the landscapes of Central Scotland have been sculptured. Let us next inquire how far the process of sculpture has been helped or hindered by the manner in which the materials have been arranged with regard to each other, in other words, by the geological structure of the district. Allusion has already been made to long lines of fault which have defined the remarkably straight boundary of the southern edge of the Highlands, and of the northern margin of the Southern Uplands. The Highland boundary-dislocation begins on the Kincardineshire coast,

and can be traced completely across the kingdom to the Firth of Clyde. It runs also across the Island of Arran, and may perhaps be yet detected in the north of Ireland. For the most part, it serves to mark sharply the line between the crystalline schists and the Old Red Sandstone; but there occur here and there on its northern side bay-like expansions of the conglomerates and their volcanic rocks, which may be seen resting upon the abraded edges of the schist. A beautiful example of this relation has been cited from Glen Turrit (Fig. 47). It is these unconformable junctions which furnish such impressive proof that the Old Red Sandstone once extended into the Highlands. The effect of the great boundary-fault is well exhibited along the coast near Stonehaven, where the conglomerates and sandstones have been thrown on end for about two miles back from the Highland rocks (p. 160). The geologist can thus walk over the exposed edges of strata amounting to somewhere about two miles in vertical thickness.

The southern margin of the valley is rather less continuously defined. But well-marked faults are traceable there also along the flank of the Lammermuir Hills, and from Peeblesshire right across the country into Ayrshire and the Firth of Clyde.

The effect of these boundary-faults has been to let down the younger formations of the Midland Valley between the older rocks on either side, or, if we look at the movement the other way, to uplift these older rocks above the younger accumulations of the intervening tract (Fig. 97 and Section No. 4 on the margin of Geological Map, Plate IV.). It is possible approximately to measure the amount of vertical displacement involved in this movement. The various sedimentary formations of the valley—taking only the Old Red Sandstone and Carboniferous—cannot on the lowest estimate have a united thickness of less than 20,000 feet. As they were shallow-water deposits, we are shut up to the conclusion that the amount of subsidence in Central Scotland must have been at least 20,000

feet, or about four miles. This gigantic displacement no doubt went on slowly and intermittently, while at the same time the regions of the Highlands and Southern Uplands were being uplifted. The subsidence may have ceased for prolonged periods, and may have been subsequently resumed. All we can say is that it lasted from the Lower Silurian, at least to the close of the Carboniferous period. During that enormously protracted interval, the subterranean movement no doubt was not a mere uniform depression of the area. There were local uplifts here and there, which brought older deposits up to the surface again. And contemporaneous with these underground disturbances and their accompanying volcanic eruptions, con-

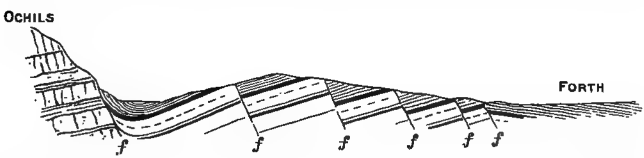

FIG. 97.—Section across the Clackmannan Coal-field. Showing how the younger formations in the Midland Valley have been let down by successive Faults, *ff*.

tinuous denudation of the surface went on apace. The evidence of ancient erosion is not less striking than that of later times. Thus thousands of feet of the lavas, conglomerates, and sandstones of the Lower Old Red Sandstone had been removed from the area of what is now the Firth of Tay before the Upper Old Red Sandstone was deposited (Fig. 100). The whole Carboniferous system down to the lower limestones was stripped off some parts of Ayrshire before the Permian sandstones were laid down.

The story of the denudation of the Midland Valley, like that of the rest of the kingdom, is thus by no means a simple one. On the one hand, it carries us back far into the records of Palæozoic time; on the other, it tells of the loss of hundreds of feet of rock from the surface of the country since the epoch of the Tertiary volcanic outbursts.

The physical features of the broad belt of lowland that

separates the high grounds of the Highlands from the Southern Uplands are much less simple and more difficult clearly to describe than those of the surrounding areas. But by taking note of the character and distribution of the rocks, we may obtain the best idea of the topography and of its relation to geological structure.

Beginning, then, at the northern edge of the valley, we find that a wide plain of Old Red Sandstone extends along the base of the Highland hills, from the North Sea to the Clyde, and is bounded on the southern side by the long ridges of the Sidlaw and Ochil Hills, and the heights of Campsie and Kilpatrick. The broadest portion of this plain lies to the north-east of Perth, where it forms the great valley known as Strathmore. But here and there its sandstones and conglomerates rise into conspicuous hills as in the heights of Finella and Caterthun. To the south-west of Perth, the same strata gradually rise towards Glen Artney until in Uam Var they attain a height of 2179 feet. The Ochil Hills are formed by a broad anticlinal fold of the volcanic rocks of the Old Red Sandstone. The axis of this plication runs in a north-easterly direction along the Carse of Gowrie, so that the great hollow of the Firth of Tay has been eroded obliquely along an arch of the underlying rocks. The one limb of the arch is prolonged into the chain of the Fife hills as far as Tayport, and thence across the firth into the east of Forfarshire. The other limb runs onward along the line of the Sidlaw Hills (Fig. 99). The Ochil Hills plunge abruptly into the plain near Stirling, where they are truncated by the large dislocations that have let down the Carboniferous rocks of the valley of the Forth (Fig. 97). But another range of heights formed by the lavas and sandstones of the Carboniferous series sets in a little way beyond, and, swelling out into the Campsie Fells and the Lennox Hills, descends upon the Clyde at Dumbarton. The same rocks have been already referred to as crossing the Clyde, rising into high ground in Renfrewshire, and stretching south-eastwards as

a moorland region between Ayrshire and Lanarkshire. This volcanic belt thus separates the valley and coal-basin of the Clyde from those of Ayrshire. To the north-east of it, Carboniferous rocks extend in a wide undulating plain throughout the rest of the Midland Valley. The stratified parts of this system would by themselves form a rather featureless district, but they rise here and there into prominent hills, such as the East and West Cairn Hills of the Pentland chain (1839 and 1844 feet) and Cairn Table, near Muirkirk (1693 feet). Their chief eminences, however, have been determined by many intercalated bands and bosses of hard igneous rocks which project into numerous prominent hills and crags. The most important interruption to the continuity of the Carboniferous plain is made by the chain of the Pentland and Braid Hills, which, composed of conglomerates, sandstones, and volcanic rocks of the Lower Old Red Sandstone, rise to a height of 1900 feet, and striking north-eastwards from the edge of the Silurian uplands, project as far as the southern suburbs of Edinburgh.

CHAPTER XVI

DENUDATION OF THE LOWLANDS

THE most cursory examination of the geological structure of the Midland Valley suffices to show that its comparatively level or undulating surface is not due to a horizontal or undisturbed arrangement of the rocks. A section across any part of the district proves that the strata, far from being flat, are curved and fractured to a remarkable degree.[1] If no change had been wrought upon the surface after the rocks began to bend, we should now find them sinking and rising into broad folds, the bottoms of the basins being sometimes several thousand feet below the tops of the arches. The lines of fault also would be marked by long ranges of vertical precipice, sometimes several thousand feet high. It is not in the least probable, however, that these geological structures ever showed themselves in such a marked way at the surface. The subterranean movements by which the rocks were folded and faulted were probably very slow. Hence the arches and fissure-walls, as they rose into the air, would at once be attacked by the denuding agents, and their detritus would be spread over the troughs that were sinking beneath the water. If the rate at which the rocks were bent and fractured and that at which they were wasted chanced to be equal, the upward folds and lines of dislocation might never make any show at the surface. And even if the rocks were

[1] See Section No. 4 on the Geological Map in Plate III. and Figs. 97, 98, 99, 100.

displaced somewhat faster than they could be worn away, the waste was perhaps always rapid enough to make the actual gain of land considerably less in proportion than the total amount of upheaval. So much, at least, is certain, that if ever the folds of the strata rose into the air as wide dome-shaped hills and mountains, they have all been planed down. Millions upon millions of cubic yards of solid stone have thus been worn away, and the surface of the Lowlands has been again reduced to a general uniformity of level.

It is desirable clearly to realise that a vast amount of rock has been removed from the surface of this region, before we

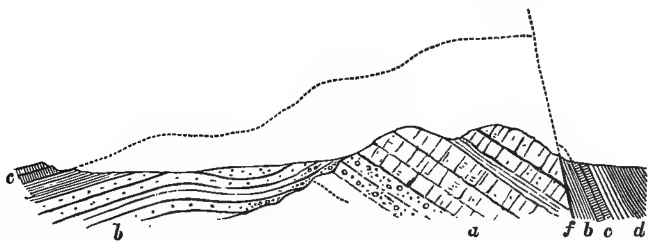

FIG. 98.—Section to illustrate the denudation of the Pentland Hills. *a*, Lower Old Red Sandstone. *b*, Lower Carboniferous rocks. *c*, Carboniferous Limestone series. *d*, Coal-measures. *f*, Fault.

begin to trace out the probable history of the present topographical features. This may best be done by examining a few typical districts and comparing the structure of the rocks with the actual form of the ground.

The Pentland Hills, which now separate the strata of the Midlothian coal-field from those of the western part of the county, were certainly at one time buried under Carboniferous deposits to a depth of probably not less than 5000 or 6000 feet. If the thickness of this covering be estimated at 5280 feet, or one mile, and the hills as fourteen miles long, by three miles broad, the mass of material worn away must have been equal to forty-two cubic miles. This lost portion would surpass by more than five times the bulk of the present Pentland Hills;

and, if it could be set down upon the Lowland Valley, it would form a group of mountains nearly a thousand feet higher than the loftiest of the Grampians (Fig. 98).

Again, the valley of the Firth of Tay, as was pointed out in the foregoing chapter, lies on what is in geological structure not a trough, but an arch. Yet not only has the whole of the top of the arch been worn away, but the work of erosion has gone on until the upward curve of the rocks has been actually hollowed out into the present wide valley. The volcanic ridges which, along the edge of the Carse of Gowrie, mount up in successive terraces, dipping away to the north-west, once rose high above what is now the Firth of Tay, and arched over till they came down into the Fife hills. The connecting portion has been removed, but we see the truncated ends of the beds rising up to the south-east from the sides of the Sidlaws on the one hand, and up to the north-west from the Fife slopes on the other. The accompanying woodcut (Fig. 99) is from a sketch taken on the top of Moncrieffe Hill, looking eastward towards the mouth of the Firth. The hills on the left side form the Sidlaw range, those on the right, the continuation of the Ochil chain into the extreme east of Fife. It will be observed that the hills on either side have their long dip-slopes in opposite directions, away from the centre of the arch, and present their abrupt escarpments towards each other. The sudden truncation of the beds of rock indicates most impressively that the amount of material which has been removed from this great hollow, if it could be set down upon the plain, would make a range of hills at least as bulky and lofty as the present Ochils. Reduced to diagrammatic form the structure represented in Fig. 99 may be expressed as in Fig. 100.

There can be no doubt that the several coal-fields of Scotland were at one time united, if indeed they did not extend continuously across the site of the Southern Uplands into the north of England. They have been thrown into folds, the

troughs of which now hold the different basins of coal, while from the intervening arches several thousand feet of sedimentary strata have been worn away (see Figs. 97, 98).

I have already indicated that much of this great denudation was accomplished even as far back as Palæozoic time. But the Tertiary basalt dykes in the Lowlands, as in the other regions of the country, furnish us with an interesting proof that there has been enormous erosion even within the comparatively brief interval that separates us from the older Tertiary periods. In the south-west of Lanarkshire and the east of Ayrshire these dykes run along the crests of some of the higher ridges. One of them, which has been already referred to as crossing the Clyde below Crawford and traversing the boundary fault of the Southern Uplands, descends into the valley of the Douglas Water, and then sweeps up along the crest of the Haughshaw and Nutberry Hills at the height of 1712 feet above the sea.[1] The vertical distance from the summit to the bottoms of the neighbouring valleys of the Nethan and Douglas Waters is about 1000 feet. It is obvious, as has already been insisted upon, that the present configuration of the surface cannot possibly be that of older Tertiary time. The lava which rose in the fissures never could have reached the tops of the hills, had there been valleys at a lower level ready to tap the ascending column of molten rock and allow it a passage to the surface. Hence we learn that long, wide, and deep valleys have been eroded in the Central Lowlands, as well as in the other districts of the country, since the age of the basalt-plateaux of the Inner Hebrides, and that the thickness of rock removed cannot have been less, and was probably far more, than 1000 feet.

It is not needful to multiply illustrations. Enough has now been said to demonstrate that throughout the whole of the

[1] The remarkable persistence of this dyke along the crest of the hills suggests that these heights may actually owe their prominence to the presence of the dyke and its influence in retarding denudation.

wide Lowlands the present undulating surface is the result of enormous denudation. The abrupt solitary crags rising from smooth-swept plains, the long wide open valleys, the truncated ends of strata protruding into mid-air, the deep defiles that trench the highest ridges, even on the watershed of the country,—all tell of long-continued erosion. Enormous dislocations, which, had they not been effaced, would have left the country an impassable network of interlacing precipices and ravines, have been all planed down, until not even a geologist would, from the form of the ground, suspect their existence. It is impossible to turn in any direction without meeting proofs of this vast and universal denudation.

FIG. 99.—View of the Firth of Tay from Moncrieffe Hill, looking east. (A valley worn out of an arch of the rocks; the long slopes of the hill-tops on either side show the dip of the beds.)

There is a vague popular notion that the igneous rocks, which form the chief eminences in the Midland Valley, have been upheaved bodily through the other formations into the light of day, and that it is to the forms assumed by them on their eruption that the present irregularities in the surface are to be traced. Such an idea, however, cannot

be held by one who knows that, on the one hand, much of the igneous material was ejected contemporaneously with the deposition of the strata among which it occurs, and has suffered, together with these strata, in all the long series of subsidences, foldings, fractures, and denudations, and that, on the other hand, even those igneous masses which have been thrust up among rocks previously formed, really consolidated beneath the surface, and are now at last exposed, only because the rocks under which they lay have been worn away. The truth is that the hills and crags of igneous origin are among the most striking proofs of denudation. They were once buried deep under stratified formations which have been removed, and they now rise up into prominent elevations, mainly because, being

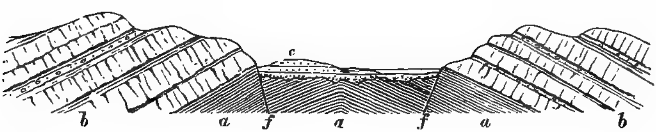

FIG. 100.—Section across the Firth of Tay to illustrate the structure of the ground represented in Fig. 99. *aa*, Lower Old Red Sandstone covered by and alternating with *bb*, various volcanic rocks belonging to the same geological period. *c*, Upper Old Red Sandstone lying on *a* unconformably. *ff*, Faults.

harder than the sedimentary rocks, they have been better able to hold their own in the long warfare with the elements.

Owing doubtless to the more varied geological structure of the region, and to its having been, throughout so large a section of geological time, an area of subsidence rather than of elevation, the history of the denudation of the Midland Valley is even less easily interpreted than that of the high grounds on either side. But without attempting to trace the stages of that long history, we shall attack the problem in its simplest form if we try to picture to ourselves a wide undulating plain, formed by prolonged denudation and catching on its surface the rain which, gathering into brooks and rivers, traced out a system of drainage-lines.

In no part of Scotland is the line of watershed more

independent of geological structure than in the Midland Valley. Descending from the ridge of Ben Lomond it strikes across the Bucklivie moors, ascends the face of the steep escarpment of the Fintry Hills, and after a circuitous course across the Campsie Fells, descends into the plain of the coal-fields. It then winds to and fro over the moors, crossing dykes, faults, and the strike of the strata with complete indifference, and at last sweeps up into the chain of the Pentland Hills, which it crosses transversely to the outcrop of the rocks. It then once more sinks into a plain and finally strikes up into the Southern Uplands.

It is evident that geological structure has here had no potent influence in the determination of the watershed. Had the rocks now visible been exposed at the surface when the watershed began to be traced, they would certainly have prevented it from ignoring them as it has done. In this, as in the other instances already discussed, we seem to be compelled to believe that the existing drainage-lines were defined before the present topographical features had been uncovered in the process of denudation. This inference is confirmed by a study of the river-systems.

Three chief rivers drain the Midland Valley,—the Tay and Forth from the Highland side, and the Clyde from the side of the Southern counties. The Tay issues from the Highlands by the narrow defile of Birnam, and crosses without deflection the line of the great boundary fault. It then winds across the Old Red Sandstone plain as far as Perth, where the ridge of the Ochil Hills runs on into that of the Sidlaws. Instead, however, of circling round this ridge, the river continues its course right across it, and then bending to the east enters the Firth. Its tributary, the Earn, a little way farther south likewise cuts through the same ridge. The careful mapping of the Geological Survey has detected evidence of a probable fissure in the defile of the Earn, the Upper Old Red Sandstone being there brought down against the older volcanic

rocks (Fig. 100). The gorge of the Tay below Perth, however, appears to be entirely due to erosion by the stream itself.

If, then, the chain of the Sidlaws once ran unbroken to the south-west, through the Hills of Kinnoul and Moncrieffe, into the range of the Ochils, of which geologically it is a prolongation, how could the Tay trench it? Two explanations may be suggested. The ridge of hills may have been cut across to a certain depth by two streams eating their way back towards each other, in the manner already pointed out as at work to the north of the Cromarty Firth. The transverse hollow thus formed would become a strait during a subsidence of the land, and might be considerably widened and deepened by the sawing action of the waves, until, after repeated changes of level, the trench was cut down so low that the drainage of the country to the north was drawn into it. But I do not think this the probable explanation.

Looking at the facts in connection with the whole problem of the denudation of the country, I believe that we must regard the trenching of the Ochil ridge to have been begun before the volcanic rocks had appeared at the surface. We must carry our imagination back to that immensely remote period when the present broad valley between the Ochil and Sidlaw range, on the one side, and the Grampians, on the other, was filled with Upper Old Red Sandstone, possibly with Carboniferous strata, and when the Tay began to flow across it. The river gradually worked its way downward through this unconformable covering. How far, when the river began its operations, the top of the anticline had been levelled off, cannot be known. But the igneous rocks, if exposed at the surface, could not have formed a continuous ridge, for the river flowed across their site. At the same time, the whole surface of the country was lowered by denudation. The sandstones, being more easily removed, were lowered faster than the volcanic rocks. Hence the former were worn down into a plain, and the latter were left protruding as a ridge. But the river, having meanwhile

taken its course across the line of the ridge, continued to saw it through as it emerged from the general degradation of the land.

Rising on the eastern flanks of Ben Lomond, the Forth issues from the Highlands by the narrow defile of Aberfoyle. It there crosses the great fault, and strikes across the vertical bands of conglomerate which form so prominent a feature in that picturesque locality. Its course is thus not only not in accordance with, but actually in defiance of, geological structure. Winding across the great plain of the Flanders Moss, the river passes through the contracted part of its valley between Stirling and the Bridge of Allan, and enters its estuary. It is probable that the great line of fracture, which here truncates the Ochil Hills, may have led to the formation of such a hollow at the surface as would guide the Forth out to sea (see Fig. 97). But the widening of the fissure into a valley has been effected by erosion. The actual fissure is only a few yards in width, but the valley at its narrowest part is more than a mile. The Abbey Craig and Craigforth are little prominences left in the removal of the rock that once surrounded and covered them. When we cast our eye over this singular strait, with its abrupt sides and its flat meadow-like bottom, stretching away into the wide mosses of Menteith on the one side and the broad Carse of Falkirk on the other, we recognise that, in the cutting down and widening of this gap, the Forth may have had much help from the sea. Yonder, indeed, not many miles to the east, is the blue firth. The level valley is plainly an old sea-bottom, and sea-shells are dug up abundantly from its sands and clays. Even now, so little is it above high-water mark that a depression of 10 feet would send the tide up the valley for eighteen miles,[1] and if the land were sunk very little more, the Firths of Clyde and Forth would meet, and a set of vexed tides would ebb and flow across the centre of Scotland. Such

[1] *Trans. Roy. Soc. Edin.* iii. 268. *Postea*, Fig. 110, p. 422.

has doubtless often been the condition of the country in the geological past.

The course of the Clyde across the Midland Valley is much longer than that of the other two rivers, and presents many additional points of geological interest. This stream

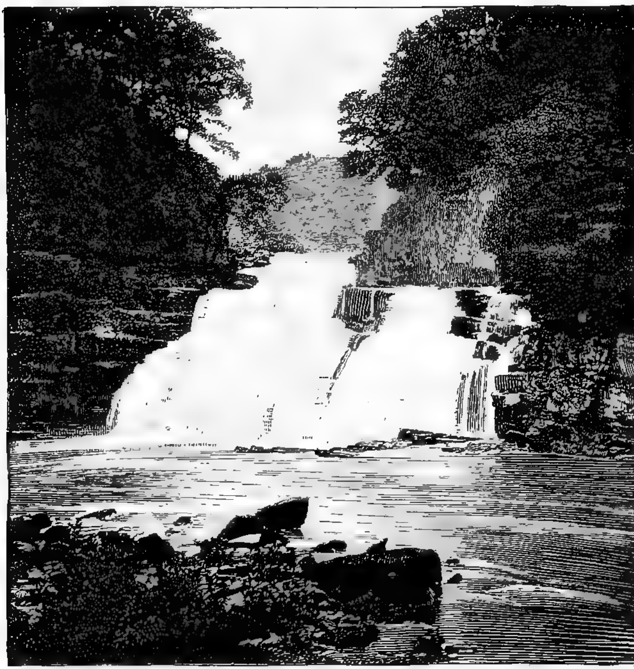

FIG. 101.—Cora Linn, Falls of Clyde.

takes its rise among the Southern Uplands, and flowing northward across the strike of the Silurian rocks, traverses the boundary fault, with which for a short way it runs parallel, and then, skirting the base of Tinto, winds across the lowlands of the Old Red Sandstone. A singular feature in this part of the Clyde's course is that it approaches within seven miles of the Tweed. Between the two streams, of course, lies the

watershed of the country, the drainage flowing on the one side into the Atlantic, and on the other into the North Sea. Yet, instead of a ridge or hill, the space between the rivers is the broad flat valley of Biggar, so little above the level of the Clyde that it would not cost much labour to send that river across into the Tweed. Indeed, some trouble is necessary to keep the former stream from eating through the loose sandy deposits that floor the valley, and finding its way over into Tweeddale. That it once took that course, thus entering the sea at Berwick instead of at Dumbarton, is possible, and if some of the gravel mounds at Thankerton could be reunited, it might do so again.[1] The origin of this pass across the watershed of the country is probably traceable to the recession of two valleys, and to the subsequent widening of the breach by general atmospheric waste.

From the western margin of the Biggar flat, the Clyde turns to the north-west, flowing across a succession of igneous rocks belonging to the Old Red Sandstone series. Its valley is there wide, and the ground rises gently on either

[1] The occurrence of salmon in the Clyde above the Falls has been explained from the relative levels of the streams in the Biggar Valley. "It is a singular circumstance," says Stoddart, in his *Angler's Companion for Scotland*, p. 417, "that salmon and their fry have occasionally been taken in the upper parts of the Clyde above its loftiest fall, which, being 80 feet in height, it is utterly impossible for fish of any kind to surmount. The fact is accounted for in this way. After passing Tinto Hill, the bed of the Clyde approaches to a level with that of the Biggar Water, which is close at hand, and discharges itself into the Tweed. On the occasion of a large flood, the two streams become connected, and the Clyde actually pours a portion of its waters into one of the tributaries of the Tweed, which is accessible to, and frequented in the winter season by, salmon." Yarrel states the highest salmon leaps to be from 8 to 10 feet; Stoddart supposes they may sometimes be more than 12 feet, and he says that in the Tummel the fish must leap 18 feet, for they are caught above the falls. (But perhaps salmon ova might be carried by birds.) The Biggar flat, however, is not the only place in that neighbourhood where the watershed of the country crosses a nearly level valley. A few miles to the north, the upper waters of the Tarth and the Medwin flow along the same meadow-land, but the former stream turns eastward into the Tweed, and the latter westward into the Clyde.

side into low undulating hills. But after bending back upon itself and receiving the Douglas Water, its banks begin to rise more steeply, until the river leaps over the linn at Bonnington into the long, narrow, and deep gorge in which the well-known Falls are contained. That this defile has not been rent open by the concussion of an earthquake, but is really the work of sub-aërial denudation, may be ascertained by tracing the unbroken beds of Lower Old Red Sandstone from side to side (Fig. 101). Indeed, one could not choose a better place in which to study the process of waste, for one can examine the effects of rains, springs, and frosts, in loosening the sandstone by means of the hundreds of joints that traverse the face of the long cliffs, and can likewise follow in all their detail the results of the constant wear and tear of the brown river that keeps ever tumbling and foaming down the ravine.

A little below the town of Lanark, the Mouse Water enters the Clyde through the dark narrow chasm beneath the Cartland Crags. There, too, though

> "It seems some mountain rent and riven
> A channel for the stream has given,"

yet it is the stream itself that has done the work. Nay, it would even appear that this singularly deep gorge, like so many other river-ravines in Scotland, has been cut out since the end of the Age of Ice, for there is an old channel close to it, filled up with drift, but through which the stream has evidently at one time flowed.[1]

Running still in a narrow valley, the Clyde, after receiving the Mouse Water, hurries westward to throw itself over the last of its linns at Stonebyres, and to toil in a long dark gorge until, as it leaves the Old Red Sandstone, its valley gradually

[1] Glacial or pre-glacial river-channels have been discovered below the boulder-clay in many parts of Scotland, and the post-glacial date of many of the present rocky gorges has been established (see Index under "Gorges").

opens out, and it then enters the great Lanarkshire coal-field. From the top of the highest Fall to the foot of the lowest is a distance of rather more than 3½ miles, in which the river descends about 230 feet, or 65 feet in a mile. From the Stonebyres Linn to the sea at Dumbarton the course of the Clyde is fully 50 miles, yet its fall is only 170 feet, or about 3.4 feet in a mile.[1]

As the Clyde, in its farther course, winds among broad meadows and fair woodlands, and murmurs through the ravines of Bothwell, no one ignorant of the geology of the district would be likely to imagine that this wide, level valley really overlies a set of strata which have been tilted up and broken by innumerable dislocations. Yet such is the fact. The flat haughs of the Clyde were not laid out until after the curved and fractured Coal-measures had been planed down, and no external trace of these underground disturbances remained.

Many other admirable illustrations of valley-erosion might be cited from the central Scottish lowlands. I have already alluded to the remarkable series of deep gorges which the streams descending from the Highlands have cut in the Old Red Sandstone of Perthshire and Forfarshire. They are true cañons, which, for picturesqueness of river scenery, are almost unrivalled in any other part of this country. They display with singular clearness the influence of variation in rock structure upon the process of erosion. The gorge of the Ericht, for example, though excavated mostly in a coarse conglomerate, reveals some of the volcanic rocks of the Lower Old Red Sandstone, and allows their contrasted forms to stand out conspicuously against the walls of conglomerate (Fig. 56). In the ravine of the Isla, an intrusive boss of porphyry makes itself prominent at the picturesque Reekie Linn. The bed of the North Esk, above Gannochy Bridge, is a mere chasm through which the stream foams in its headlong course from

[1] See Petermann, *Edin. New Phil. Journ.* xlvii. p. 309.

the Highland glen above. The Old Red Sandstone, as already remarked, yields the most striking river scenery in Scotland.

In following the details of the vast denudation which has levelled the Lowlands, it is not uninteresting to trace, as in the case of the Highlands, how each marked variety of rock has imparted its own peculiar outlines to the scenery. By much the most noticeable rocks in this respect are those of igneous origin—the felsites, andesites, diabases, dolerites, basalts, and tuffs. I do not know any large mass of them that does not

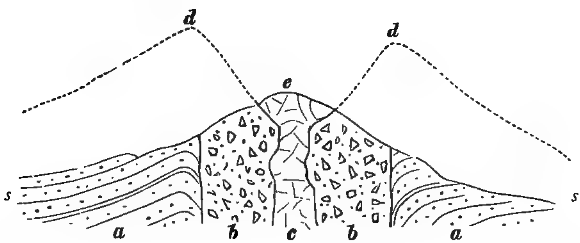

FIG. 102.—Section of Volcanic Neck. *a*, Strata through which the volcanic vent has been opened. *b*, Coarse agglomerate filling up the chimney of the volcano, and traversed by a column of basalt (*c*), which probably marks the last eruption. The position of the crater is indicated by *e*, the original form of the volcano by the dotted lines *dd*, and the present form of the ground by the line *ss*. This structure is illustrated by many volcanic necks in Fife and the Lothians, as Largo Law, Saline Hill, Hill of Beath, Binn of Burntisland, Arthur's Seat, Binns Hill.

form a ridge or hill; even their smaller protrusions usually project at the surface as little mounds, or craggy knobs. But not only so; their leading varieties weather each in a fashion of its own. Thus the felsites tend to decompose into smooth conical eminences, usually coated with turf which, when broken here and there along the slopes, allows screes of detritus to slide down the hill. The noblest example in the whole of the district is Tinto, a huge mass of bright flesh-coloured rock rising to a height nearly 1700 feet above the Clyde, which washes its base, and 2300 feet above the sea. Smaller and less perfect cones may be traced towards the north-east, from Quothquan into the Pentland Hills, and far to the east they

reappear in the trachytic bosses of Traprain and North Berwick Law. North of the Forth, a constant succession of eminences, terraced or conical in form, marks the position and abundance of igneous rocks, from the andesite plateaux of the Campsies and Ochils, through the more isolated heights of Fife and the long ridges of Forfarshire, to the far coast of Kincardineshire. The cones, when united to each other, form connected chains of hills, as in the Sidlaws.

It is hardly necessary to remark, that though the cones of the Scottish Midland Valley sometimes look not unlike volcanoes, as North Berwick Law, Saline Hill, and Largo Law, their present form is entirely due to denudation. The connection between internal form and internal structure may be understood by comparing the sketch of Largo Law in Fig. 96 with the diagram of the arrangement of the rocks in a volcanic neck as represented in Fig. 102. It will be observed that no trace of the original cone remains, the existing prominence of the hill being due to the greater durability of its rocks, which has enabled them to withstand the general abrasion of the surface better than the surrounding strata. The reason that such hills take a conical outline seems to be the same as that which I have suggested with regard to quartzite mountains. Felsites and other igneous rocks which are uniform in texture, likewise structureless and readily decomposing tuffs and agglomerates, instead of breaking up into large blocks, crumble into loose angular shivers or into mere gravel and earth which slide down and form a smooth covering for the lower parts of the hill, leaving the upper slopes exposed to continual waste, so that, as the hill moulders away, it grows more conical. In the end, however, the cones become blunted at top, and as the angle of the declivity lessens, the rate of waste is proportionately decreased.

The diabases, dolerites, and basalts, on the other hand, splitting up along their joints into large blocks, are marked by a more craggy and rugged outline. Where they occupy a

considerable breadth of surface, they rise into broken irregular ground, protruding through the soil in rounded hummocks and "tors" of dun-coloured stone, the surface of which crumbles into rich brown loam. Hence they present a curious blending of bright green sward with bare lichen-crusted or brown crags

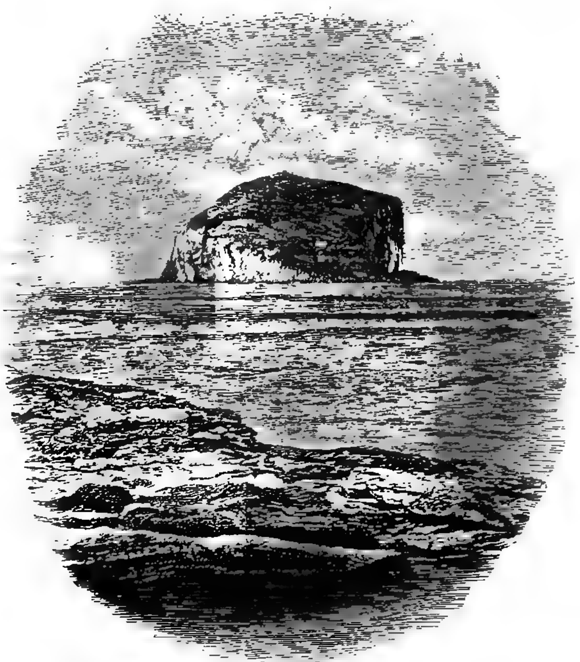

FIG. 103.—The Bass Rock, from the south.

and boulders. The numerous parallel joints in these rocks afford pathways for rain, springs, and frosts. The texture of the masses, too, varies indefinitely; sometimes it is so firm and compact, that on the bare weather-beaten surface, the black titaniferous iron crystals glance in the sun, while in other places it is decayed into a mere loose yellow or brown sand. Between these two extremes, every variety of hardness may be

seen, and hence probably the hummocky aspect of the ground over which these rocks prevail. The eruptive rocks, when intruded as sheets or sills into the Carboniferous sandstones and shales, sometimes protrude in tabular, steep-fronted crags, such as Binny Craig, Salisbury Crags, and the Lomonds of Fife, though more usually they form somewhat hummocky ridges. Where they have risen in bosses or vents, they project in isolated crags, like those of Edinburgh Castle and Dumbarton Castle. Though such detached eminences throughout the Scottish Midlands are generally formed of some of the basic eruptive rocks, examples occur where the material is of an acid kind, as in the two impressive sea-girt crags—Ailsa Craig, a mass of granophyre, rising in the midst of the Firth of Clyde, and the Bass Rock (Fig. 103), a boss of phonolite which guards the entrance of the Firth of Forth. In all cases, no matter what be the material or the circumstance of its eruption, the present prominence of the igneous rock is entirely due to its superior durability in the progress of denudation, which has removed the softer stratified formations that once surrounded and covered it.

To the effects of denudation also must be ascribed an interesting topographical feature of the Midland Valley known as "crag and tail." The worn edge of an eruptive mass projects as a "crag," and the strata which rest upon it, though swept off the top of the eminence and removed from the sides, are often preserved on the declivity behind, under the drift deposits which form in this way a "tail" (Fig. 104). Around Edinburgh, where these features were first noticed, the crag usually faces the west, as in Salisbury Crags, Calton Hill, and Castle Rock, because the escarpment or outcrop of the rocks is in that direction, and consequently any rock which stood out above the others would naturally give rise to an eminence, steep on the west side and shelving on the east. Where the dip of the strata is to the west, and therefore their escarpment to the east, the crag looks eastward, of which there

is an instance in Corstorphine Hill.[1] But the "tail" of drift deposits points away from the direction whence the ice-sheets of the glacial period moved, as will be further alluded to in the next chapter.

It is where the strata are not too highly inclined that the tabular form assumed by intruded sills can best be observed. The igneous rock then forms a cake or capping that has protected the softer strata underneath. In the West Lomond of Fife, for example, the Upper Old Red Sandstones rise almost horizontally to a height of 900 feet above the vale of the Eden, their bared edges being cut away into a steep declivity. Over them comes a group of Carboniferous strata followed by a thick sill or sheet of dolerite, which runs as a dark precipice

FIG. 104.—Section of the form of hill in the Lowlands of Scotland known as "Crag and Tail." *a*, "Crag" of basalt or other eruptive rock. *b*, "Tail" of softer rocks which have been worn away from around the hard igneous mass. *c*, Hollow often found in front of the crag. *d* Covering of drift.

along the crest of the slope, and supports a little patch of sandstone and limestone, on which lies the surviving fragment of a higher sill that forms a knob on the conical summit 1713 feet above the sea. It is plain that a mass of rock some 1700 feet thick has been hollowed out of the valley of the Eden, and, as the strata are nearly flat, and show here and there their naked edges along the green slopes, with the overlying band of eruptive rock at top, the hill presents a suggestive monument of denudation. The tourist who visits Loch Leven is

[1] See the original descriptions of Sir James Hall, *Trans. Roy. Soc. Edin.* vol. vii.; Maclaren, *Geol. Lothians*, pp. 52, 218. "Crag and Tail" in the Midland Valley is often, however, a topographical feature due mainly to the influence of the geological structure of the rocks upon their denudation, though modified by the various agents at work during the Glacial Period. (See "Memoir on the Glacial Drift of Scotland," in *Trans. Geol. Soc. Glasgow*, vol. i. p. 30.) The subject is further discussed at p. 391.

placed at the best point of view for seeing the hill to advantage. The broad placid surface of that characteristically Scottish sheet of water sweeps across to the very foot of the Lomond chain, which rises from the level foreground with a dignity not always seen even in a much loftier hill.

When the igneous rocks occur in large flat sheets, piled over each other to a great thickness, they give rise to those terraced outlines already described as so characteristic of the islands of the Inner Hebrides. The most conspicuous example of this feature in the Lowlands is to be found in the range of the Campsie Fells, along the southern flank of which the successive sheets of andesitic lava and tuff may be traced by the eye from a distance of several miles, rising above each other in successive bands of dark rock and grassy slope. Down the eastern side of the Firth of Clyde also, the continuation of the same rocks prolongs this structure through the hills between Greenock and Ardrossan. The terraced outlines of the southern end of Bute and of the Cumbrae Isles are due to the same cause.

It is thus the igneous rocks which, in the general waste of the surface, have, by their greater permanence, given rise to most of the diversities in the scenery of the Lowlands. The stratified rocks, as a whole, are singularly featureless. They form the tame level groundwork which is relieved by the eruptive masses. Although, now and then, they rise into such pointed heights as Cairn Table, or into rounded eminences like the conglomerate and sandstone hills of the Pentland chain, already alluded to, or high rolling moorlands such as lie on the confines of the counties of Lanark and Ayr, yet over the low grounds they are for the most part buried under a smooth-swept covering of drift, so that any minor features which they might have lent to the landscape are concealed. It is in such confined spaces as ravines, or along the sea-margin, that we can best learn after what fashion the softer rocks of the Lowlands yield to the attacks of time. The

coast-line on both sides of the island supplies many illustrations of these features. Where the strata are of tolerably uniform composition, gently inclined, and traversed by vertical joints, they may give rise to lines of sea-cliff like those of sandstone to the north of Arbroath. Where they consist of frequent alternations of different materials and are inclined at steep angles, they produce a rocky shore which runs out into reefs and retires into bays according to the durability or otherwise of the stone. The shores of Fife afford a long series of examples of this type of coast-scenery, especially in the outcrop of the Millstone Grit between Pathhead and Dysart. The coast between St. Andrews and Fife Ness abounds in picturesque minor features arising from the complicated arrangement of the Lower Carboniferous strata.

The disappearance of the older stratified deposits under a widespread mantle of drift leads us to consider how far the scenery of the Midland Valley has been modified by the ice-sheets and glaciers of the long Ice Age. This subject will form the theme of the next chapter.

CHAPTER XVII

THE GLACIATION OF THE LOWLANDS

WHEN the great ice-sheet began to settle down upon Scotland, the main features of the broad Midland Valley, like those of the rest of the country, were probably very much what they are still. During the passing of the Ice Age many of the minor details of the scenery were modified or obliterated; hills were rounded and smoothed, while many an old valley and river-course was partially or wholly filled up with boulder-clay. The whole country was, as it were, smothered up in drift, and hundreds of new hillocks and mounds were scattered over its surface. Yet the larger elements of the landscape underwent no marked change.

Throughout the Lowlands, no chain of hills seems to have been high and broad enough to nourish an independent group of glaciers.[1] But, as we have already seen, the great ice-sheets from the Highlands on the one side, and from the Southern Uplands on the other, streamed down into the low grounds and across these to the sea. Hence the projecting rocks have that ice-worn surface so characteristic of Scottish scenery. They still retain abundantly on their sides and summits the striation and moulding which mark the direction in which the ice moved. From the position and trend of these markings,

[1] In the higher valleys of the Ochils there are indications of a small snowfield that nourished valley-glaciers after the great ice-sheet had retired from that region.

we learn that the massive ice of the great Highland area came down into Strathmore and kept steadily southward in such force as to mount over the chain of the Sidlaw and Ochil Hills, and to have been massive enough to envelop and bury the Pentland Hills, for striæ have been found on the top of Allermuir Hill, at the north end of that chain, at a height of 1617 feet above the sea. Hence the stream of ice that passed eastwards across the Lothians must have been a good deal more than 1600 feet thick. It has left its mark on every prominent hill and crag in the district. Some excellent examples of ice-striæ may be seen on the side of the Queen's Drive round Arthur's Seat, just above the crag of Samson's Ribs, where the ice has forced itself through a narrow gully on the south side of the hill. The north side of North Berwick Law retains some remarkably fresh ice-groovings which show that hill to have been enveloped and ground down by the ice in its eastward progress. Farther west a huge body of ice descended from the north into the basin of the Clyde, filling the Firth, overriding the hills on either side, and passing across the site of Renfrewshire and the north of Ayrshire and Lanarkshire until it met the ice that was streaming northward from the Southern Uplands into the plains of Ayrshire. Thus, a vast mass of ice, moving down the hollow of the Firth of Clyde into St. Patrick's Channel and augmented by the mass that flowed from the Southern Uplands and the Lake District, filled the basin of the Irish Sea, swept round the Isle of Man, and creeping still southward, joined the sheet that came down from the mountains of Wales. The general trend of the various branches of the ice-sheet, in their course across the Lowlands, will be most intelligibly followed by an examination of the accompanying Map of the Glaciation of Scotland (Plate IV.). The reader can there trace the march of the different ice-streams that poured into the Midland Valley and, uniting their mass, moved eastward and westward into the sea. With so vast a thickness of ice creeping over the land, it is no

wonder that there should be *roches moutonnées* even on the tops of many of the Lowland ridges, and that the rocks should show such widespread proofs of having had their roughness rounded off.

I have left for fuller consideration in this chapter the results of the abrasion of the surface of the country by the ice-sheet, as manifested in the abundant detritus that has been left in the valleys and all over the lower grounds. Before the Ice Age began, Britain had probably stood for a long time above the sea. Its superficial rocks had consequently been exposed to protracted sub-aërial disintegration. Much of the decomposed rock would of course be washed off by rain. But over the flatter surfaces of ground, where the transporting power of rain would be least, the rotted rock probably accumulated *in situ*. In the south of England, which the ice-sheet did not reach, a considerable thickness of such decomposed material may now be seen, representing probably a prolonged period of decay. Thus, along the coast of Cornwall the slates or killas form picturesque ranges of cliff, the upper portions of which consist of yellow and orange-coloured, thoroughly decayed and oxidised material, which might not at first be supposed to be a continuation of the dark purple or blue solid stone which in the lower part of the precipice is washed and eroded by the waves. In the same region, the granite is so decomposed for many yards below the surface that it can be dug out with a spade. In Dorset the various Mesozoic formations have likewise decayed down to depths of 20 feet or more, and the upper rotted band may be traced for miles along the cliffs. This covering of weathered material affords some idea of what may have been the general condition of the surface of the country before the ice-sheet settled down upon it. When the ice began to form and to creep over the land, the superficial layer of rotted rock would first be removed. The ice thus found a vast quantity of loose material ready to be pushed onward and to be made into various kinds of "drift."

Of all the varieties of detritus left behind by the ice, the most universal and characteristic is the *till* or *boulder-clay*. This interesting deposit may be seen exposed in banks and cliffs along the course of almost any Lowland brook, from the sea-shores up to a height of 1700 feet or more. In the Carse of Stirling it attains a depth of 160 feet.

The boulder-clay has had much influence on the character of the scenery of the Lowlands. As its surface is for the most part smooth and undulating, it gives to the landscape an aspect of gentleness and tameness that would probably be greatly lessened if the clay could be stripped off, so as to show the bare rock underneath. The long, smooth boulder-clay slopes, which have been already described in the account of the surface of the Highlands and Southern Uplands, are more marked and more abundant in the Lowlands, where the deposit spreads over much more continuous areas. In like manner, the water-courses which have so generally been eroded through the clay, present almost everywhere sinuous grassy bluffs, here and there cut into fresh scars as the streams attack them, and as springs cause landslips along their fronts.[1]

But the most marked surface-feature presented by the boulder-clay of the Lowlands is its tendency to assume the form of long ridges ("drums" or "drumlins"), parallel with the general trend of the striæ on the rocks, as described in Chapter XIV. These ridges frequently start on the lee-side of one of the crags or heights already referred to (p. 384) in connection with the phenomenon of Crag and Tail. Each mass of hard, prominent igneous rock which rose up in the course of the ice-sheet deflected the ice to either side and allowed the till to be

[1] Scott, with his keen eye for topographic detail, noted that the Teviot, in its course across the Old Red Sandstone, flows in some places between bluffs of red boulder-clay.

> "Is it the roar of Teviot's tide
> That chafes against the scaur's red side?"
> (*Lay of Last Minstrel*, I. xii.)

and the word "scaur" is explained to mean "a precipitous bank of earth."

heaped up behind it, as sand and gravel are collected behind a boulder in the channel of a stream. The distribution of the ridges brings clearly before the eye the direction in which the streams of ice moved off the high grounds towards the sea. These features may be seen all over Central Scotland. In the Lothians, for instance, the trend of the "drums" runs nearly east and west. Hence roads which follow that direction may continue for long distances without any marked variation of level, whereas those which run north and south are a succession of rapid ups and downs.

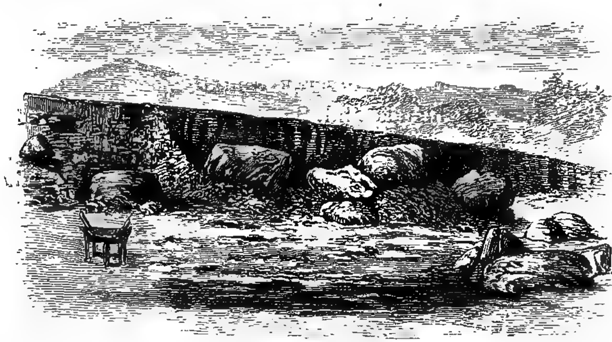

FIG. 105.—Section of boulder-clay, Craiglockhart Hill, Edinburgh. Exposed when the foundations of the Hydropathic Establishment were being dug out.

Few localities are better fitted at once to interest and perplex a geologist than a cliff of boulder-clay. He sees before him a stiff sandy clay, without any traces of stratification, full of stones of every size up to blocks several feet in diameter (Fig. 105). These are usually grouped without order, large boulders and small pebbles being scattered indiscriminately through the clay from top to bottom. They are stuck at every angle, their smoothed and polished surfaces are covered with ruts and striæ (Fig. 106) running chiefly along the longer diameter of the stones, and if the face of the rock below be uncovered, it may be seen to retain the same markings (Figs. 73, 74, 75, 76). On careful examination, these stones are found to consist

chiefly of fragments from the rocks of the immediate neighbourhood, but with a proportion of pieces that may have travelled from a distance of sometimes twenty or thirty miles. In a Coal-measure district, for instance, there is a mixture of bits of sandstone, shale, ironstone, coal, and other Carboniferous strata, with a few pieces of the harder rocks of an adjacent geological area. In the Old Red Sandstone and Permian districts the boulder-clay is red; over the coal-fields it is black or dark blue; in the Silurian tracts, among

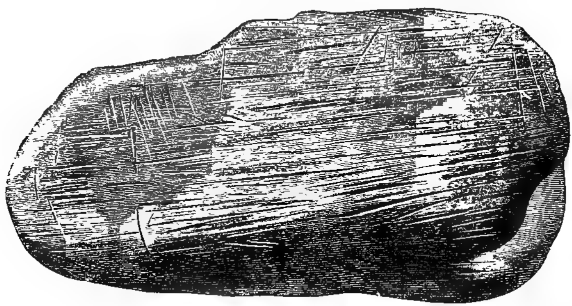

FIG. 106.—Striated stone from boulder-clay of North Medwin Water, Lanarkshire.

pale shales, it is fawn-coloured, thus evincing even in its colour its local origin. This local character, therefore, shows that the deposit cannot have been brought from a distance, but must have been produced on the whole in each district where it occurs,[1] although its minor proportion of stones from

[1] That Arctic bergs probably had nothing to do with the formation of this deposit is indicated by the absence of far-travelled stones in the clay. After many years of exploration, I have never succeeded in detecting in the Scottish boulder-clay a single stone which might not have come from rocks not many miles away. I have been in the habit of taking percentages of the stones at different localities in a district, and the result has invariably been to establish the prevailing local character of the deposit, and to point out the direction from which the ice moved. In the course of a ramble from Berwick-on-Tweed to the mouth of the Humber, the late Sir A. C. Ramsay and I did not meet with traces of Scandinavian rocks till we had reached the mouth of the Tees and

some distance affords proof of a certain amount of transport of material.

As an illustration of the composition of a typical till or boulder-clay, a list of the percentage of stones may here be given which was taken by me in 1863 from the sea-cliff at Newhaven, near Edinburgh, referred to on p. 58 as now entirely built over. It should be noted that this locality lies in the midst of the sandstones and shales of the Carboniferous system of Central Scotland, and that to the west of it numerous doleritic sills traverse these strata.

White and grey sandstones	30	per cent
Black shale	12	,,
Queensferry limestone, cement stone, and ironstone	7	,,
Encrinite limestone	3	,,
Quartz-pebbles	4	,,
Dolerites of various types	37	,,
Basalt	6	,,
Tuff	1	,,

Of these included stones the sandstones, shales, limestones, and igneous rocks, amounting in all to 93 per cent, are local and need not have travelled more than six or eight miles. Of the remainder the 3 per cent of crinoidal limestone may have come from the nearest outcrop of the rock at a distance of about fourteen or fifteen miles, while the 4 per cent of quartz-pebbles may conceivably have been derived from the conglomerates of the Old Red Sandstone or of the Lower Carboniferous series twenty-five or thirty miles off.

Above the lower boulder-clay, from which the foregoing list was taken, lay an upper more sandy till, in which there was more evidence of transport from some distance. The proportion of local stones amounted to 63 per cent; that of those

they became more and more common the farther south we went, showing that the trend of the Scandinavian ice across the floor of the North Sea lay towards the eastern or south-eastern coast of England. Fragments of granite, gneiss, mica-schist, "rhomben-porphyr," and other Norwegian rocks are not infrequent in the boulder-clay of East Anglia.

from ground twenty-five or thirty miles distant (Ochil Hills, etc.) reached 28 per cent, and of those from the Highland border (forty miles) 9 per cent.

The mode of formation of boulder-clay, for many years one of the obscurest problems in geology, cannot be said even yet to have been completely solved. After much study of the question in Northern Europe and in North America, it is now generally admitted that the almost universal striation of the boulders, their local origin, and the tumultuous unstratified character of the whole deposit prove the till to have been ground up by a moving mass of land-ice. As the ice crept downwards, it partly enclosed and partly overrode rock-detritus, crushing the loose materials against each other and upon the bare rock underneath, and producing thereby the smoothed, polished, and striated surfaces so characteristic of the boulders and of the *roches moutonnées* all over the country. When the ice-sheet melted away, the underlying accumulation of debris was left scattered over the land, thickest on the valleys and plains, and thinning away up into the mountains, where it would naturally merge into the materials gathered by the later glaciers into which the ice-sheet finally shrank. Part of the till would be deposited on the sea-floor, under the ice that moved outwards from the land.

Although the main features of the present topography had been determined by prolonged sub-aërial denudation before the ice settled down upon the surface of the country and began to produce the boulder-clay, the hills and valleys, in many of their minor details, no doubt differed from the appearance now familiar to us. Probably the ground was more roughened with crags of mouldering rock, for it has been smoothed by the attrition of the ice-sheet and by the spread of a mantle of drift over its surface. The deposit of this drift necessarily led to the burial of many of the minor features of the topography, which, for the most part, still lie concealed from view under the boulder-clay. More especially has this fate overtaken

many ancient river-beds and water-channels. Though, on the whole, the streams still flow in their original valleys, they do not always occupy their pre-glacial beds. On the contrary, these are in many cases still filled with till, and the modern channel has been eroded since the disappearance of the ice. All over the country examples of this episode in the history of the Ice Age may be gathered. The accompanying diagram represents a case displayed by the Water of Gregg, above Barr, in the south of Ayrshire. The ancient channel was a capacious hollow excavated in the Silurian greywackes and

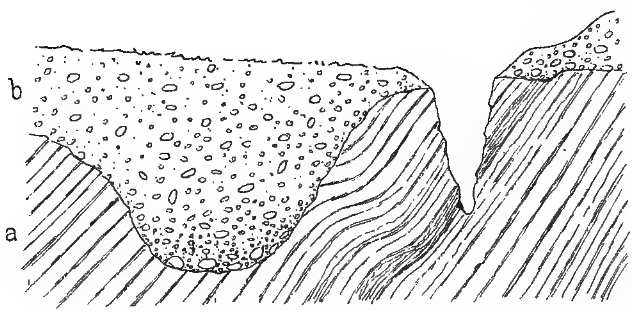

FIG. 107.—Section of pre-glacial and modern water-channels, Water of Gregg, Ayrshire. *b*. Boulder-clay. *a*. Silurian greywackes and shales.

shales. It has been completely obliterated by the deposit of 100 feet of boulder-clay over it. Diverted from its previous channel, the stream has been employed in carving out for itself a new and smaller channel 70 to 80 feet deep in the same hard rocks. In the Central Lowlands, as in the Highlands and Southern Uplands, a large proportion of the rocky ravines in which the streams flow has been dug out by running water since the end of the Ice Age (pp. 192, 350, 379).

It is obvious that here and there, under favourable conditions, not only parts of the pre-glacial topographical details, but even portions of the actual land-surface, with its soil, vegetation, and animal remains, might escape demolition, though such fortunate

survivals are rarer than could be wished. The conditions under which they may be most hopefully searched for are illustrated in Fig. 108, where under the lee of a crag of red shales, a portion of the sub-aërial detritus from that crag, protected by the rock behind it, has not been entirely removed by the overlying boulder-clay.

The boulder-clay furnishes us with some scanty indications of the denizens of the country during the long period which it represents. Bones of the mammoth, reindeer, and of probably

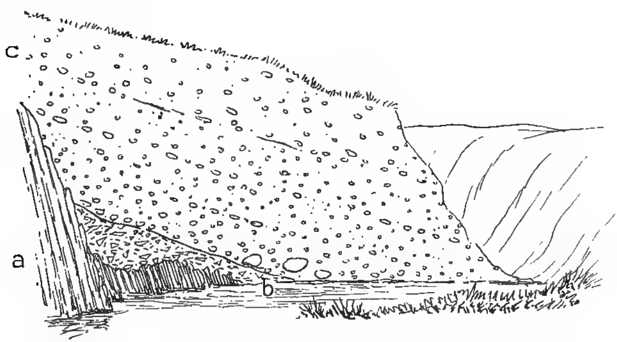

FIG. 108.—Section in the Albany Burn, Barr, Ayrshire. *c*. Rudely stratified gravelly boulder-clay with large granite blocks and striated stones. *b*. Unscratched angular debris of *a*. *a*. Vertical red shales (Old Red Sandstone).

several species of oxen and deer have been from time to time dug up. And doubtless the relics of other animals will yet be discovered in the older glacial deposits of Scotland, for scanty though the fauna might be, it need not perhaps have been less than that of modern Greenland. Besides the remains of mammalia, the Scottish till near Airdrie and in other places has yielded remains of land-vegetation—thin beds of peat and trunks of trees lying in what seem to have been lakes or water-courses that occupied hollows of the glacial detritus. These intercalations show that the boulder-clay is not one continuous deposit, but the result of a succession of advances and retreats of the ice-sheet, between which there were prolonged intervals

of milder climate, when forests and marshes covered the land and the northern mammals found food. In some places, the boulder-clay contains marine shells. The highest level at which these have been met with in Scotland is 510 feet. At one time it was believed that the mere occurrence of such shells in a deposit sufficed to prove the submergence of the locality, the minimum amount of depression being indicated by the height of the place above sea-level. But we now know that the ice-sheet of the Glacial Period moved along and out of some of the sea-basins around our shores. In the Moray Firth, as already stated, the ice slanted up over the low plains of Caithness, pushing along, in its progress, the mud, stones, and shells that lay on the sea-floor and are now found in the boulder-clay. In the Firth of Clyde, also, the ice ground up the clay and shells of the sea-bottom, as is shown by the shelly boulder-clay of Arran, Carrick, and Wigtownshire. The extent of the submergence of Scotland during the Ice Age has not yet been satisfactorily proved.

It would be beyond the scope of the present volume to enter farther into the history of the boulder-clay. Enough has probably been said to let the reader see how much geological interest there is in a deposit which spreads so widely over the Lowlands of Scotland, and so largely influences the character of their landscapes.

Of later date than the boulder-clay, but still belonging to the Ice Age and probably connected with the 100 feet terrace to be more particularly noticed in next chapter, comes another group of deposits which, though they only slightly affect the scenery in the Clyde and a few other parts of the Scottish coast, are of such importance, from the light they cast upon one aspect of the country during its glacial condition, that brief allusion may be made to them here. They consist of certain beds of brick-clay, well seen along the low grounds on the banks of the Clyde below Glasgow, and on the shores of many of the sheltered bays

and sea-lochs of the west of Scotland. They occur also along the eastern shore, at intervals, from the Forth to the Moray Firth. Their chief interest to the geologist arises from the fact that they contain an abundant series of shells, from which strong additional evidence is obtained as to the former intensity of the climate. Sixty years have passed away since the occurrence and true character of these organic remains were ascertained by the late Mr. James Smith of Jordanhill.[1] Cruising with his yacht among the kyles and lochs of his own Firth of Clyde, he had been collecting materials from the raised beaches of the west to show that the land had undergone a comparatively recent elevation. One day, in company with a friend, he chanced to walk on the beach of a little bay in the Kyles of Bute. His attention was directed to a number of shells lying among the shingle, but different from any which his companion or himself had ever dredged in the adjoining sea. On closer inspection, it was found that the shells had been washed out of a bed of clay, where they existed by hundreds, and that their association on the beach with the recent shells thrown up by the tides was merely an accident. What then constituted the difference between the shells of the clay-bed and those living in the neighbouring kyles and firths? It was at first supposed that some of them were of new species. In order to ascertain if this were the case, and to be better able to compare the contents of the clay-bed with the shells still inhabiting the British seas, Mr. Smith instituted a careful dredging of the basin of the Firth of Clyde. A more charming employment can hardly be conceived. In the midst of some of the finest scenery in the west of Scotland, within easy reach of all the comforts of home, and yet among scenes almost as lone and retired as

[1] *Proc. Geol. Soc.* 1839. For many years no man was better known or more highly esteemed on the Clyde than this veteran yachtsman. It is a pleasure to recall his little cabin, with its shelf of geological literature, and its kindly occupant beaming with scientific enthusiasm and the heartiest good-nature.

the wildest Highland tarn, his self-imposed task was to bring up to the light of day the denizens of these quiet sea-lochs and bays, to explore the deeps and shallows, sunken reefs, shoals, and abysses, and thus, while his vessel perhaps lay asleep on the face of a summer sea, to walk, as it were, in fancy along the sea-floor many fathoms underneath, and to pick up there, from its nestling-place among tangle or sand, many a tiny shell which had never before been known to live around the coasts of Britain. The result of his explorations, and of those subsequently carried on by Forbes, Macandrew, Jeffreys, and others, went to show that the assemblage of shells in the clay had a strongly northern character, that among them were some which are now rare in British seas, though common in the far north, while a few no longer live around our shores, but are confined to the boreal and Arctic regions. The value of these researches was not thoroughly perceived at the time, but they were eventually found to lend a powerful support to the attempts of geologists to account for some of the superficial phenomena of the country by the agency of ice.

The flat platform that extends along the Clyde below Glasgow, and spreads out to a breadth of between three and four miles at Paisley, has been cut out of the brick-clays in which these Arctic shells occur. A similar terrace, but at a higher level, forms a conspicuous feature at Falkirk. To these terraces further allusion will be made in Chapter XVIII. But the clays are chiefly to be found on the beach. The land has been elevated since they were formed, and they have been partly carried up above the sea, but those formed in deeper water are still below the line of high-water mark.

Among the superficial formations which, overlying the till, and belonging to the closing ages of the Glacial Period, have notably influenced the scenery of the Midland Valley, must be placed those long rampart-like ridges of gravel and sand known as *kames* in Scotland, *eskers* in Ireland, and *ösar* in

Scandinavia (Fig. 109). Notwithstanding all that has been said and written about them, no thoroughly satisfactory explanation of them has yet been given. They look not unlike the earthen mounds of antique fortifications, but are loftier and longer than any such fortifications which have survived in this country. They rise up sharply and boldly, sometimes from the side of a hill, sometimes along a wide moor, and sometimes across a valley. They do not appear to occur in Scotland except in the neighbourhood of hills and rising ground. They may be traced at all levels—from less than a hundred feet above the sea up to at least a thousand feet. They consist of sand, of gravel, or of both, varying in texture to the coarsest shingle. They contain no fossils, save now and then a few sea-shells, or the bones of some terrestrial mammal.

These ridges have been a fruitful source of wonder and legend to the people. It was a quaint and beautiful superstition that peopled such verdurous hillocks or "tomans" with shadowy forms, like diminutive mortals, clad in green silk, or in russet grey, whose unearthly music came faintly sounding from underneath the sod. The mounds rose so conspicuously from the ground, and, whether in summer heat or winter frost, wore ever an aspect so smooth and green, where all around was rough with dark moss-hags and sombre moor, that they seemed to have been raised by no natural power, but to be in very truth the work of elfin hands, designed at once to mark and guard the entrance to the fairy world below. The hapless wight who, lured by their soft verdure, stretched himself to sleep on their slopes, sank gently into their depths, and after a seven years' servitude in fairyland awoke again on the self-same spot. Like young Tamlane,

> "The Queen of Faeries keppit him
> In yon green hill to dwell."

Throughout the south of Scotland, these more obtrusive

minor features of the scenery are often traced up to the agency of Michael Scott and his band of witches and warlocks. According to a tradition in Roxburghshire, the kames are the different strands of a rope, which a troublesome elfin was commanded to weave out of sand. The strands were all prepared, but when the imp tried to entwine them, each gave way, and hence the broken parts of the kames have remained to this day. Michael seems to have had no small amount of work in altering the surface of the country. There is a deep gash through a sandy ridge at the south end of the Pentland Hills, and not far off stands a green conical sand-hill. The wizard is said to have dug the trench and piled up the hill in the course of a single night. It was he too that

> "Cleft the Eildon Hills in three,
> And bridled the Tweed with a curb of stone."

Fanciful and sometimes grotesque as these legends are, they are yet interesting, inasmuch as they indicate the prominence of the phenomena, and the difficulty of accounting for them by any of the common and familiar operations of nature.

In the Midland Valley many excellent examples of kames are to be found. One of the best districts is that through which the Caledonian Railway passes between the Cobbinshaw Reservoir and Carstairs. Another extends up the valley of the Clyde to Symington Junction. A third may be seen from the railway in going from Linlithgow to Falkirk and a fourth from Bridge of Allan to Perth. Vast mounds of sand and gravel have been piled up on the low watershed between Greenloaning and Auchterarder.

That the kames are connected in some way with the action of ice is shown by their disappearance as we advance southward from Scotland through the northern counties of England, and by the occurrence of occasional striated stones in them, and of large boulders lying upon them. But that they are not the ordinary moraines of glaciers, as some

geologists have imagined, seems to be conclusively indicated by the general absence of angular rubbish, by the well-worn water-rolled character of the stones, and by the stratification which is almost everywhere visible in them, when a sufficiently large section is exposed. They seem to point to abundant streams of running water from the rapid melting of snow and ice.

Connected with the kames, and perhaps nearly as old, is a series of tarns and of former lake-basins now filled with peat. I do not know a district where these features play so conspicuous a part in the scenery as in the eastern parishes of the county of Lanark, to which allusion has just been made. Behind the little village of Carstairs, for instance, the ridges of sand and gravel run one after another from south-

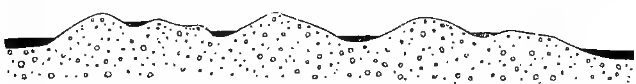

FIG. 109.—Section of sand and gravel ridges (kames) at Carstairs, Lanarkshire. (The dark portions mark little basins of peat occupying the site of former tarns.)

west to north-east, somewhat like the larger mounds of a tract of sand-hills by the sea. They are singularly tortuous in their course, so that they often come together, and in this way form loops which enclose basins of water or of peat. One such hollow in particular is so circular, and shelves so steeply into the pool which fills its bottom, that it at once suggests the crater of a volcano like one of those in the Eifel. As the kames there stretch across the mouth of a broad valley, they must at one time have dammed back the drainage so as to form a lake. Since then they have been cut through by the Mouse Water, and the lake has thus been drained. But its site is still visible in the wide moss-hags and bogs of the Carnwath Moor, and in at least one place a shrunk remnant of the water, with the peat creeping into it, may even yet be seen. The gradual inroads of the peat upon the smaller

ponds and lochans is also well exhibited. Standing on the crest of one of the higher ridges, the observer can at once understand how, after the formation of these mysterious mounds, there must have been dozens of little tarns or pools lying in dimples and basins among the kames. But he can see only three or four which have not been converted into peat-bogs.

I may here refer to the lakes of the Midland Valley, the vast majority of which lie in hollows of the boulder-clay or of the sandy and gravelly drift. As these hollows were due to original irregular deposition, rather than to erosion, they have no intimate relation to the present drainage-lines of the country. They vary in size from mere pools up to wide sheets of water, embracing several square miles of area. As a rule, they are shallow in proportion to their extent of surface. Though still sufficiently numerous in the Lowlands, they were once greatly more so, for, partly from natural causes and partly by artificial means, they have been made to disappear. Ayrshire, for instance, was once abundantly besprinkled with lakes, but within the last few generations their numbers have been so greatly reduced that only a few remain, and black peaty meadows serve to mark the sites of those which have been drained. The largest sheets of fresh water in the Midland Valley are of this class, as in the examples of Loch Leven and the Loch of Menteith. Here and there a few rock-basin tarns may be seen, as among the Cleish Hills in Fife.

The last illustration which I shall give of the influence of the various agencies of the Glacial Period upon the scenery of the central valley of Scotland is to be found in the erratic blocks. Smaller in size and less numerous than those in the Highlands and Southern Uplands, they nevertheless impress the imagination more vividly from the greater contrast they offer to the rocks among which they occur, and the demonstration they afford of transport from a distance. In

many a Lowland parish, where little or no naked rock may come to the surface, the smooth ridges of till will be found with their scattered boulders sometimes many tons in weight. In such places

> "A huge stone is sometimes seen to lie
> Couched on the bald top of an eminence;
> Wonder to all who do the same espy,
> By what means it could thither come and whence,
> So that it seems a thing indued with sense,
> Like a sea beast crawled forth, that on a shelf
> Of rock or sand reposeth, there to sun itself."[1]

Unhappily, the progress of modern agriculture is inimical to the preservation of these stones, and they have as a consequence disappeared from the more cultivated districts. But in many a mossy tract, especially round the flanks of the main hill ranges, they may still be counted by the score. I have already alluded to the grey granite boulders which lie strewn over the lower grounds of Carrick, in such numbers as to look at a little distance like flocks of sheep (Fig. 91). So conspicuous are the erratic blocks of the Lowlands as to have long attracted the notice of the peasantry, and so strange sometimes are their positions, and so markedly do they often differ in composition from the general character of the surrounding rocks, that, like the kames, they have been from the earliest times a theme of endless wonder. Many a wild legend and grotesque tale of goblins, witches, and elfins has had its source among the grey boulders of a bare moor.[2] "Giant's Stone,"

[1] Wordsworth's *Poems of the Imagination*, xxii.

[2] In wandering over the south of Scotland I have met with some curious traditions and beliefs of this kind. The following was told me on the spot by an intelligent native of the village of Carnwath. Before farming operations were there carried to the extent to which they have since arrived, large boulders, now mostly removed, were scattered so abundantly over the mossy tract between the River Clyde and the Yelping Craig, about two miles to the east, that one place was known familiarly as "Hell Stanes Gate" [road], and another "Hell Stanes Loan." The traditional story runs that the stones were brought by supernatural agency from the Yelping Craig. Michael Scott and the Devil, it appears, had entered into a compact with a band of witches

"Giant's Grave," "Auld Wives' Lift," "Witches' Stepping Stanes," "Warlock's Burdens," "Hell Stanes," and similar epithets, are common all over the Lowland counties, and mark where, to the people of an older time, the singularity of these blocks proved them to be the handiwork, not of any mere natural agent, but of the active and sometimes malevolent spirits of another world. Nor need this popular belief be in any measure a matter of surprise. For truly, even to a geological eye, which has been looking at the same phenomenon for years, each fresh repetition of it hardly diminishes the interest, nay, almost the wonder, with which it is beheld. We have dispossessed the old warlocks and brownies; and yet, though we can now trace, it may be, the source from which the stones were brought, and the manner in which they were borne to their present sites, their history still reads like a very fairy tale. There they lie crusted over with mosses and lichens; tufts of heather and harebell and fern nestle in their rifts, while all around perhaps is bare bleak moorland. How came they there? The whole record of their derivation and transport rises before the mind with fresh novelty, and we find ourselves instinctively going over again the old familiar induction. They have not tumbled from any cliff, for they

to dam back the Clyde. It was one of the conditions of such agreements that the name of the Supreme Being should never on any account be mentioned. All went well for a while, some of the stronger spirits having brought their burden of boulders to within a few yards from the river, when one of the younger members of the company, staggering under the weight of a huge block of greenstone, exclaimed, "O Lord! but I'm tired." Instantly every boulder tumbled to the ground, nor could witch, warlock, or devil move a single stone one yard farther. And there the blocks lay for many a long century, until the rapacious farmers quarried them away for dykes and road-metal.

Another explanation of a somewhat different kind was given by a stone-mason among the Carrick Hills, who, on being asked how he imagined that the hundreds of granite boulders in that district came to lie where they do, took a little time to reply, and at last gravely remarked that he "fancied when the Almichty flang the warld out, He maun hae putten thae stanes upon her to keep her steady."

rise boldly above the soil, where not another vestige of naked rock appears within sight. They have not been transported by rivers, for they stand perched on the summits of the hills, high above all the streams, and even out of hearing of their sound. They cannot have been washed up by floods and oceanic convulsions, for some of them are not only of enormous size, but consist of rock foreign to the district, and not to be found nearer than perhaps fifty or sixty miles, beyond successive ranges of hills and valleys. What force, then, could carry these huge masses to such great distances, across wide and deep valleys, and lines of high hills? And so we are led back once more to the ice-sheet, and recognise how amply its former presence is proved.

A little examination of the boulders suffices to show the march of the ice. The direction of their transport always coincides with that of the striæ on the rocks, and proves both to be due to the same cause. Thus, dotted over the chains of the Sidlaw and Ochil Hills, lie blocks of gneiss, quartzite, and schist that have come across from the opposite ranges of the Grampians. Boulders of the same kind have been carried to the furthest eastern shores of Fife and Forfarshire, and doubtless they lie abundantly scattered over the floor of the North Sea. They are likewise found both on the plains and hills to the south of the Forth, while beyond the Clyde they are strewn across Renfrewshire and the north of Ayrshire. Large fragments from the granite mountains of Carrick and Galloway have been carried over the heights and hollows to the north-west and north, up to, and perhaps beyond, the town of Ayr.

When the long Ice Age came to a close, the Midland Valley, freed at last from its envelope of ice and snow, must have worn a very different aspect from that which had distinguished it before glacier or ice-sheet had begun to modify its surface. Its old pre-glacial roughness had been, to a large extent, planed down, and new hollows had doubtless been scooped out by the ice; but a thick mantle of clay and sand

had been spread over the ground, leaving only the harder and higher masses of rock to rise above the general monotonous undulations. The old ravines and water-courses were, for the most part, buried under these accumulations, and only here and there have the streams returned to them. Since then, too, the other denuding agents have been ceaselessly at work upon the surface of the land. The wide covering of drift has been furrowed in all directions, and in innumerable places has been cut through to the bare rock below by brooks and runnels. The larger streams have dug ravines in it, nay, in numberless cases, they have gone farther, and after trenching the drift, have even hollowed out deep gorges in the rock underneath. And if we turn to the hills that rise out of the wide plain of drift and lift their bare rocks to the sky, proofs of the same waste meet us on every side. The hummocks of diabase are split and broken ; the crags of basalt are rent and splintered ; the base of the cliffs and the sides of the hills are cumbered with the ruin that marks how quietly, yet how well, the rains, springs, and frosts of centuries have done their work. Slowly the impress of the ice is fading away, and though thousands of years may pass before all trace of its action is obliterated, the time must nevertheless come when the present surface of the land shall have disappeared as completely as the sand ripple of last night's tide was washed away by the tide of this morning.

CHAPTER XVIII

THE LATEST MODIFICATIONS OF SCOTTISH SCENERY

Besides the effects of denudation all over the surface of the land, from the tops of the highest hills down to the level of the sea, whereby the aspect of the surface is undergoing continual alteration, other changes have considerably modified the appearance of many districts, since the last glaciers died out and the long Ice Age came to an end. Some of these have been brought about by that intermittent rise of the country above its previous level which has added a selvage of new land to some parts of the coast. Other modifications have arisen from the growth and decay of vegetation and the filling up of lakes in the interior of the country. In the one case, we have the phenomenon of raised beaches; in the other, that of peat-mosses. To each of these characteristic features of Lowland scenery some attention is due.

That there were movements of the land during the Glacial Period in Britain is almost certain, though, as I have already said, the evidence formerly relied upon to prove submergence may need to be revised. Not improbably the general level of the country at some time in the course of that long period was considerably higher than it is now. But we know that towards the close of the time, the level, at least in Scotland and the north of England, was lower. The marine terraces found along the coast-line mark former levels at which the land stood, and probably indicate a gradual uprise, with

long pauses when the country remained stationary. But that there were also downward movements seems to be put beyond question by the "submerged forests," which here and there occur below high-water mark.

If, while standing at a lower level than it does now, the country rose again slowly with long intervals of rest, each of these pauses would give the sea an opportunity of cutting a notch, or horizontal terrace, along the margin of the land, and laying down upon it the sand, gravel, or silt of an ordinary beach. A succession of such terraces, "raised beaches," or "strand-lines," would thus be traceable at different elevations above the present sea-level, becoming generally fainter according to their height, for the highest being the oldest would necessarily have been longest exposed to denudation. In Chapter IX. a brief account has been given of these platforms as they affect the scenery of the western and northern coast-lines of the Highlands. I have shown that they consist sometimes of shelves or notches (*Seter*) cut by the sea out of solid rock, and at other times of deposits of sand, gravel, and shingle which have been laid down upon such sea-eroded platforms. The shores of the Midland Valley present the same general features, though on the whole less impressively than in the Highlands. Where the strand-lines in this region are platforms of erosion, they have been for the most part cut out of boulder-clay. Their inner margins are thus defined by winding grassy banks with occasional scars of clay—a scenic feature which is well displayed along both sides of the Firth of Forth. Here and there the shelf has been cut out of solid rock, as in the striking group of three terraces notched in the volcanic agglomerate of the Kincraig headland, near Elie in Fife. But generally the platform bears a deposit of littoral sand and gravel. Though traces of more elevated terraces are here and there visible, the highest which comes notably forward as a feature in the scenery of the Lowlands, as in the rest of Scotland, is that which lies about 100 feet above the

present sea-level. One of the best localities for observing the share taken by this platform in the coast scenery of the Midland Valley is to be found in the district between Falkirk and Stirling. Its broad level surface has there been deeply trenched by streams, and has likewise been cut away along the outer margin so as to descend to the next terrace in a line of steep grassy bluffs. The materials composing the platform consist of finely-laminated clays and sands, which were probably accumulated while floating ice still drifted about in our bays and estuaries. These deposits may be traced eastward along the shores of Fife as a well-marked terrace which ascends into the valleys and bays of the old coast-line, and here and there disappears against a projecting group of hills. The platform is well displayed to the west of Torryburn, between Inverkeithing and Dunfermline, again at Kinghorn, Kirkcaldy, and Pathhead, and still more strikingly between Largo and Crail and in the neighbourhood of St. Andrews. The same persistent feature stretches likewise along the southern coast of the estuary.

The wide tract of level ground upon which the 100-feet terrace of Stirlingshire so abruptly descends is another marine terrace, known as the Carse of Falkirk, "carse" being the name applied in Scotland to such level tracts of alluvial land bordering an estuary (Fig. 110). The carse at the head of the Forth marks a former sea-level about 50 feet above the present one. It has been cut out of the glacial drift deposits, and has a coating of dark mud and sand containing recent shells. A lower terrace (about 25 feet) has in large measure replaced the 50-feet platform in the main part of the estuary.

These terraces, in so far as they consist of littoral deposits, are best developed, as might be expected, in such sheltered places as the upper reaches of estuaries, where sediment could accumulate, and they were, therefore, probably never continuous for long distances. Not only are they well displayed in the Firth of Forth; they are admirably seen in Strath Earn,

above the Firth of Tay, and in the Carse of Gowrie. They may likewise be traced down the Clyde from above Glasgow.

The most recent and therefore most prominent of the raised beaches in the Midland Valley is that which lies at a height of about 20 or 25 feet above high water. It runs down the more sheltered indentations of the coast-line as a flat selvage of rock, or of littoral deposits, varying in breadth from six or seven miles to not more than a few feet. Its deposits are horizontal layers of sand, gravel, or clay, often full of littoral shells. As this is the freshest and most accessible of the Scottish raised beaches, a description of its features such as they appear along the margin of the Firth of Clyde and its islands may be taken as typical for the raised marine platforms of the whole country.

From the inner margin of this old sea-beach, the ground often rises precipitously. Where the material that has been cut away by the sea is boulder-clay, it winds in steep bluffs which, though, on the whole, covered and protected by a coating of grass and herbage, are liable here and there to be gashed by the landslips that are caused by percolating water. Where, on the other hand, the material consists of firm stone, as in Bute and Arran, it has generally been scarped into cliffs and perforated with caves, while the flat terrace beneath, whether of rock or of gravel and sand, is sometimes roughened with prominent crags and worn pillars of rock, like the tangle-covered skerries and sea-stacks of the modern coast-line. These prominent rocks, whether on the terrace, or rising steeply from its inner edge, are feathered over with ferns and ivy and trailing briers; they are tinted with mosses and lichens, and gay with many a bud and blossom. Luxuriant bunches of hart's tongue hang from the roofs of the caves, and swallows build their nests in the crannies of the cliff. But could we divest the rocks of all this tapestry of verdure, could we strip the terrace of its mantle of gardens and fields, its highways and hedgerows, its villas and hamlets, its busy

seaport towns and watering-places, we should then lay bare a former sea-beach. Instead of the level corn-fields and orchards of the present terrace, we have to imagine a tract of sand or mud; for the mosses and lichens, ferns and flowers, a shaggy covering of sea-weed; in place of swallows, martins, and rock-pigeons, we must people the rocks once more with gulls and auks and cormorants; we must in imagination watch the tides come eddying across the terrace up to the base of the cliff: and we may thus restore that old coast-line to the condition in which it existed when already a human population had found a home upon these shores.

The 25-feet beach must be more or less familiar to every one who has visited almost any part of the coast-line of Central Scotland. On the east side of the country, it runs as a conspicuous terrace along the margins of the Firths of Forth and Tay. It is visible in sheltered bays along the storm-swept coasts of Forfar, Kincardine, and Aberdeen. On the west coast, its low green platform borders both sides of the Firth of Clyde, fringes the islands, runs up the river beyond Glasgow, and winds southwards along the coast of Ayrshire and Wigtown into the Irish Channel. Where it consists of a platform of sand and gravel, its outer or seaward edge forms a low bank or cliff which offers but a feeble resistance to the progress of the waves. Consequently its waste is one of the most noticeable features of the Scottish coast-line. The terrace is being continually reduced in breadth as slice after slice is cut away from it, and in some places it has entirely disappeared. The various stages in this denudation are impressively displayed along the coast of Fife (*ante*, p. 59).

As in the north of Scotland, there are traces here and there of still younger terraces in the Midland Valley. These are perhaps best seen along the coast of Argyllshire between Toward Point and the mouth of Loch Striven. They evidently indicate a much shorter pause of the sea at their respective levels. When the land in its upward movement had

reached the line of the 25-feet beach, it must have remained there for so long a time as to be able to cut a notch in the sandstones and other shore rocks, to pierce them with caves and gullies, to wear them down into stacks and skerries, and to strew over the terrace a level sheet of shingle, gravel, or sand. Few geological events of the minor kind have been more serviceable to man than this prolonged rest of the sea at the line of the 25-feet terrace, and the subsequent elevation of the marine platform into land. It has given him an invaluable site for his maritime towns and villages. Along many a coast-line, where, before the elevation, the ground shelved down in a cliff or steep bank to the sea, he now finds ready to his hand a firm level terrace, bounded by the former cliff on the one side, and by the present sea-beach on the other. Leith, Burntisland, Dundee, Arbroath, Cromarty, Rothesay, Greenock, Ardrossan, Ayr, and other towns on the coast stand, either wholly or in part, on this terrace. Indeed, it is in no small degree owing to the facilities afforded by the terrace that the banks of the Clyde and its firth are so thickly fringed with towns, villages, and watering-places. At Glasgow, which is partly built on the same platform, some interesting relics of the early history of these geological and historical features have been found. From the silt and sand of which the terrace there consists, no fewer than eighteen canoes have at different times been obtained, some of them from under the very streets and houses. It is not uninteresting to mark at how early an epoch the advantages of that part of the Clyde, as a maritime station, were recognised.

I have already alluded to the singular contrast between the present aspect of the Clyde and its appearance during the bleak Glacial Period. Another contrast, not less striking in its features, and bearing a closer human interest withal, is suggested by these relics of the early races. To-day all is bustle and business. Ships from the remotest corners of the earth come hither with their merchandise. Vast warehouses and stores

are ranged row upon row along the margin of the river, and in these are piled the productions of every clime. Streets, noisy with the rattle of wheels, and the tread of horses, and the hum of men, stretch away, to the right hand and the left, as far as the eye can reach. The air is heavy with the smoke belched out from thousands of chimneys. And so, day after day, the same endless din goes on; every year adding to it, as the streets and squares creep outward, and the tide of human life keeps constantly flowing. But how different the scene when our hatchet-wielding forefathers navigated these waters! Down in the earth, beneath those very warehouses and streets, lies the bed of the old river, with the remains of the canoes that floated on its surface—silent witnesses of the changes that have been effected, not less on the land than on its inhabitants. We can picture that dim, long-forgotten time, when the sea rose at least five-and-twenty feet higher in the valley than it does now, and covered with a broad sheet of water the site of the lower parts of the present city of Glasgow. We see the skirts of the dark Caledonian forest sweeping away to the north, among the mists and shadows of the distant hills. The lower grounds are brown with peat-bogs and long, dreary flats of stunted bent, on which there grows here and there a hazel or an alder bush, or, perchance, a solitary fir, beneath whose branches a herd of wild cattle browse. Yonder, far to the right, a few red deer are pacing slowly up the valley, as the heron, with hoarse outcry and lumbering flight, takes wing, and a canoe, manned by a swarthy savage, with bow across his shoulders, pushes out from the shore. The smoke that curls from the brake in front shows where his comrades are busy before their huts hollowing out the stem of a huge oak, that fell on the neighbouring slope when the last storm swept across from the Atlantic. And there stretches the broad river—its surface never disturbed save by the winds of heaven, the plunge of the water-fowl, or the paddles of the canoes—its clear current never darkened except when the rain-clouds have gathered far away on the southern

hills, and the spate comes roaring down the glens and waterfalls, and hurries away red and rapid to lose itself in the sea. Such was the landscape when our ancestors first looked upon it. How came it to undergo so total a change? It is not merely that man himself has advanced, that he has uprooted the old forests, extirpated the wild cattle, driven away the red deer to the fastnesses of the mountains, drained the lakes and peat-bogs, covered the country with corn-fields and villages, and built along the margin of the river a great city. True, he has done all this, and has undoubtedly been the chief agent in the general change. But nature too has helped him. Those vast forces that are lodged beneath the crust of the earth have slowly upheaved the land, and have converted a large part of the bottom of the old estuary into good, dry ground, covered with the richest soil, and fitted in no common degree for the growth of streets. And hence, where his forefathers floated their rude boats he builds his warehouses, and on tracts that were ever wet with the ooze of river and sea, and bore few other inhabitants than the cockle and mussel, he now plants his country villas and lays out his pleasure-grounds.

The disappearance of the ancient woods deserves more than a mere passing allusion, for it has materially influenced the present scenery of the country, and it has a still further interest from the close way in which it is linked with human history. Duly to appreciate the nature and extent of the change which is traceable to this cause, it is necessary to bear in mind the magnitude of the forests which, when man first set foot in Scotland, swept in long withdrawing glades across its surface, —the wide black mosses and moors, the innumerable lakes and fens, dense and stagnant indeed on the lower grounds, but which, in the uplands, were the sources whence streamlets and rivers descended through glen, valley, and woodland, into the encircling sea. Beasts of the chase, and among them some that have been for centuries extinct here, abounded in these ancient forests; birds of many kinds haunted the woods

and waters; fish swarmed in lake, river, and bay. Among such primeval landscapes did our aboriginal forefathers excavate their rude earthen dwellings and build their weems of stone; from the fallen oaks they hollowed out canoes, which they launched upon the rivers and lakes; and through the thick glades of the forest they chased the wild boar, the *urus*, the bear, the wolf, and the red deer. The traces of these old scenes are still in part preserved to us. From the peat-mosses and alluvial flats that mark the sites of former lakes are exhumed canoes, stone celts, and other implements, as well as ornaments fashioned by the early races, together with trunks of oak and pine that represent the trees of the ancient forest, and likewise bones of the animals that roamed through its shades. It is from such records that we know both what used to be the aspect of the country and how it has come to be so wholly changed.

It is a common opinion that the peat-mosses of Scotland are of a comparatively modern date—not older, indeed, than the Roman invasion, because "all the coins, axes, arms, and other utensils found in them are Roman." But these relics are better understood now than they formerly were; and though in some cases their Roman date may be beyond doubt, they are admitted to belong generally to the earlier time, known to the antiquary as the Bronze Period. Their evidence, therefore, cannot prove more than that the mosses in which they have been found may be as late as the time when the natives of this country fashioned their implements of bronze. The occurrence of the antiquities in the peat is obviously of itself no proof that the peat is not actually very much older than they. They may, in fact, have been dropped on the moss when it was in a soft, boggy condition, and so have sunk to some depth beneath the surface. It would require not a little careful observation to show conclusively that the portion of the peat lying above such remains was really formed after they were left there by their human owners. If, however, the remains occur not in

the substance of the moss, but below it, on what was once a soil, or a lake-bottom, and if they are of such a kind, or in such a position, as to show or to make it probable that they were left exactly in the place where they still lie, the inference may be drawn that they are of older date than the peat which overlies them. Tried by such a rigid test as this, comparatively few of the Scottish peat-mosses can at present be proved to be later than the Roman invasion. There is ground for believing that some have been formed since that time, and that others, though later than the first coming of man into the country, are far older than our era. There can be little doubt that peat-bogs would begin to accumulate as soon as aquatic vegetation commenced to grow in the hollows from which the ice and snow of the Glacial Period had retired. The lower parts of many of our mosses probably date back to that ancient time when the vegetation of the country was still Arctic in character, and consisted largely of dwarf willows and birches, though the higher portions may belong to much more recent periods, when the flora had become that of a temperate climate.

The history of the peat-mosses of Scotland has yet to be investigated, for at present our knowledge of them is of the most meagre and fragmentary kind. From the depths of the older mosses we may hope to learn more than is now known regarding the vegetation of the Ice Age. It is not from Scottish localities that our information has been obtained respecting the fauna and flora of the Glacial Period. The very intensity and prolongation of the glacial conditions in the northern part of Britain made the chances of the preservation of organic remains there less probable. But it may not be too much to hope that from Scottish peat-mosses further relics may yet be obtained of the animals that preceded, or were contemporary with, the earliest human population of the country—the mammoth, rhinoceros, reindeer, musk-ox, bear, Irish elk, the progenitors of our present races of cattle, and other denizens

of forest and glade. In recent years some interesting evidence has been found by the Geological Survey in the neighbourhood of Edinburgh and in Fife that some of the alluvial plains in these districts mark where lakes lay when the climate was still thoroughly Arctic. From the deposits of these lakes well-preserved specimens have been recovered of such plants as the Arctic birch (*Betula nana*) and willow (*Salix herbacea*), while abundant remains have been found of *Apus* (*Lepidurus*) *glacialis*, a little crustacean that still lives in the fresh-water pools of Spitzbergen and Greenland, which are only thawed during the brief summers of these Arctic lands.

Peat is formed in lakes, or on wet, marshy ground. The water of a shallow lake is gradually displaced by the growth of marsh-plants, creeping steadily from the margin to the centre, until a surface of matted vegetation has been formed that extends treacherously over the water. This process may be seen going on in many parts of the country. So rapidly does it sometimes advance, that the sheet of water becomes almost visibly smaller every year, while the encircling morass gains in proportion. Such seems to have been the origin of not a few of our peat-mosses, and especially of the older ones. The pools and lakes formed by the unequal accumulation of the boulder-clay and other deposits of the Glacial Period, have, in the vast majority of cases, passed into basins of peat. Their disappearance would largely depend upon their relative size and depth; the smaller and shallower being the first to be filled up. That many of them were still sheets of water when man was living in the island, is proved by the canoes and "crannogs," or pile-dwellings, which have been found buried under the peat.

Peat-mosses not only mark the sites of lochs and tarns; some of them cover the ruins of ancient woodlands. That some mosses in Scotland have sprung up after the destruction of forests which once grew there, is shown by the trunks and branches of trees which are found among the lower parts of the

peat. It was, indeed, the destruction of the forests that gave rise to such mosses. A large number of trees, prostrated at the same time and left to rot on the ground, would intercept the runnels and surface drainage. In this manner, stagnant swamps would be formed, in which water-mosses would readily take root; and, by degrees, peat would accumulate. There are several ways in which a forest may be destroyed and turned into a peat-moss. The growth of a thick mass of wood for many successive centuries on the same spot tends to impoverish the soil, and, in the natural course of events, the trees must decay and give way to other races of plants, which will draw nourishment from the mouldering trunks. And thus, on tracts which at one period bore a dense array of wood, there might spring up in later ages wide, brown morasses and peat-bogs. Again, when a hurricane, sweeping across the country, has uprooted many trees, the fallen trunks and rotting leaves, by collecting moisture and facilitating the growth of marshy vegetation, may in like manner give rise to a peat-moss. Or the weight of snow in a severe winter may be so great as to break the branches, and even drag down the trees upon each other: "*nec jam sustineant onus sylvæ laborantes.*" Or, lastly, man, armed with axe and hatchet, may come and fell oak and beech and pine, taking, it may be, little or none of the wood away, but leaving it there to rot, and to gather around and over it a mantle of peat-forming plants.

Peat-mosses have probably arisen in each of these ways in Scotland. In the Forest of Mar, Aberdeenshire, large trunks of Scotch fir, which fell from age and decay, were soon immured in peat, formed partly from the decay of their perishing leaves and branches, and partly from the growth of *Sphagnum* and other marsh-plants. About the middle of the seventeenth century, on Loch Broom, in Ross-shire, over the site of a decayed forest, peat was dug in less than fifty years. In 1756 the whole Wood of Drumlanrig, in Dumfriesshire, was blown down and experienced a similar fate. And other cases are

known where, at the bottom of the moss, lie the remains of old forests, with their trees prostrated all in one direction, showing the point from which came the storm that hurled them to the ground.[1]

The Moss of Kincardine, in the upper part of the valley of the Forth, appears to owe its existence, at least in one place, to the fact that the thick oak forest which once covered its site was felled by man. Below the moss the stumps and trunks of large trees were found crowded as thickly upon the clay as they could be supposed to have grown there. The roots were still fixed in the clay, as when the trees were in life, and the stems had been cut down at a height of about two feet and a half from the ground. Marks of a narrow axe were sometimes traced on the lower ends of the logs, completing the proof that the wood had been cleared by human agency.[2] Here we see how a district of fair woodland—the home, doubtless, of many a stag and hind, and the nesting-place of many a cushat dove and blackbird—has been turned by man into a waste of barren morass and mire—a place of shaking bog and stunted heath, where he cannot build his dwelling nor plant his crops, and from which he can extract nothing save fuel for his hearth. Such has been the condition of these districts for many a long century; and it is only within the last two or three generations that an exertion has been made, with much labour and cost, to strip off the thick covering of peat, and restore again to the light of day that old soil which nourished the early oak forest. The succession of deposits on the Carse of the Forth is shown in Fig. 110.

So long as the conditions of growth remain favourable for the marshy vegetation, peat continues to be formed, and the bogs become gradually thicker. But where these conditions change in such measure as to kill off the peat-producing mosses,

[1] Rennie's *Essays on Peat*, pp. 30, 65.

[2] Tait, *On the Mosses of Kincardine and Flanders. Trans. Roy. Soc. Edin.* iii. p. 266.

the peat ceases to accumulate. Its surface, as it dries, becomes a fit soil for other plants, notably for heather, which extends completely over it and sends its roots far down into the black spongy substance. The matted roots of the heath form an upper fibrous layer of peat. In the end, firs and other trees may take root upon the tract.

An old dead peat-moss, that is, one where the peat is no longer being formed, sometimes affords an excellent illustration of the fact that nothing on the surface of the land is allowed to remain unchanged. So long as the peat is growing, it can generally resist denudation, but when its growth ceases, it

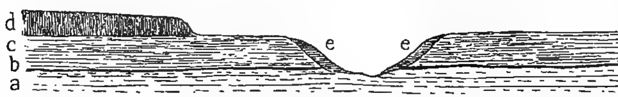

FIG. 110.—Section of the deposits under the Carse of the Forth, near Port of Menteith. *e*, Alluvial mud of present river partially filling up the channel. *d*, Peat (13 to 18 feet), containing trunks of oak, hazel-nuts, etc. *c*, Dull brown clay (20 feet), containing, especially towards the bottom, recent marine shells (*Cardium*, *Ostrea*). *b*, Bed of peat (from a few inches to 1 foot), persistent for a long distance. *a*, Fine muddy pale grey clay locally called "sleek," extending everywhere under the Carse and forming the "running mud" met with in borings and pits.

becomes liable to attacks from the denuding agents. This may be well observed along the flat crests of hills and in low cols, where level ground has been afforded for boggy vegetation. No longer growing, or at least not growing vigorously enough to ward off atmospheric disintegration, the peat cracks up and is dried and blown away as dust by wind, or washed down by rain. It is to this cause that the singularly rugged surface, known in the south of Scotland as "moss-hags," is due. Deep gutters and pools are dug out of the crumbling mass by wind and rain—black, soft, and treacherous, which the inexperienced pedestrian can only pass in dry weather, and even then often like the march of the Salian priests, "*cum tripudiis sollennique saltatu.*"

This general desiccation and decay of the higher peat-

mosses may be noticed all over the Southern Uplands. The black cappings of peat which cover so many of the flat hill-tops, and extend down their sides, may now be seen to be shrinking up again towards the top. They have a ragged fringe, some parts running in long tongues down the slope, or in straggling isolated patches. These features are well displayed on the high grounds above Loch Skene. The long, bare, flattened ridges have each their rough scalps of peat, of which the black, broken edges hang down the slopes of brown heath and bent, while far below are the green valleys, with their clear winding streams, and their scattered shepherds' hamlets.

The enumeration of the later changes in the scenery of Scotland would be incomplete if it included no reference to those which have been brought about by man. Human agency must be reckoned as a not unimportant factor in the geological mutations which now befall the surface of the land. It would lead me into too wide a discussion, however, were I to attempt to enter fully here into this subject. To some of man's operations in this country I have already alluded, and others may be merely cited. He has uprooted the old forests, drained many of the mosses, and extirpated or greatly reduced in numbers many of the wild animals of ancient Caledonia. In place of the woods and bogs he has planted fields and gardens, and built villages and towns; instead of wild beasts of the chase, he has covered the hills and valleys with flocks of sheep and herds of cattle. The cutting down of the forests and the draining of the mosses has doubtless tended to lower the rainfall, and generally to lessen the moisture of the atmosphere and improve the climate. Sunlight has been let in upon the waste places of the land, and the latent fertility of the soil has been called forth; so that over the same regions which, in Roman times, were so dark and inhospitable, so steeped in dank mists and vapours, and so infested with beasts of prey, there now stretch the rich champaign of the Lothians,

the cultivated plains of Forfar, Perth, and Stirling, of Lanark and Ayr, and the mingling fields and gardens and woodland that fill all the fair valley of the Tweed, from the grey Muirfoots and Lammermuirs far up into the heart of the Cheviots.

In effecting these revolutions, man has introduced an element of change which has extended through both animate and inanimate nature. He has ameliorated the climate, and by so doing has affected the agencies of waste that are wearing down the surface of the land. The rivers are now, probably, less in size than they were even in the days of the Romans, and there may be fewer runnels and streamlets. The old mosses acted as vast sponges, collecting the rain that fell upon them or soaked into them from the neighbouring slopes, and feeding with a constant supply the brown peaty rivulets that carried their surplus waters to the lower grounds. The evaporation from these wide swampy flats could not but be extensive, and the rainfall was thus, in all likelihood, proportionately great. But the clearing away of the forests and of the peat-mosses has removed one chief source alike of the rivulets and of the rain. The amount of denudation by the combined influence of rain and streams might accordingly be supposed to be less, on the whole, than it was eighteen hundred years ago. But we must bear in mind that the extent to which draining has now been carried all over the country has had the effect of allowing the rain to run off more easily into the rivers, which consequently swell and fall again more rapidly than they used to do. Floods or "spates," though the annual rainfall may be the same or less, have thus a tendency to be more sudden and violent than formerly, and hence the increased amount of erosion performed by rivers in flood may be more than an equivalent for the diminution of their ordinary state.

Among the plants and animals of the country, too, traces of the influence of man's interference are everywhere apparent. He has altered the character of the vegetation over wide

districts, driving away plants of one kind, such as the heaths, to put in their stead those of another type, like the cereals, thus materially modifying the aspect of the country. The gradual change of climate superinduced by him must also have affected the vegetation of the country; some herbs grow now more abundantly than they formerly did; or they may now be able to flourish at a higher level than of old. Others, to which the change has been unfavourable, may have been greatly thinned in numbers, and even extirpated altogether. In like manner, the coming of man has worked mighty transformations in the animal world. Over and above the extirpation of the beasts of the forest, and the introduction of foreign forms into the country, he has waged incessant war against those which he considers injurious to his interest. He has thus altered the natural proportion of the different species to each other, and introduced a new element into the universal "struggle for existence." No species, whether of plant or of animal, can notably increase or diminish in number without, of course, thereby exerting an influence upon its neighbours. And here a boundless field of inquiry opens out to us. Man's advent has not been a mere solitary fact, nor have the alterations which he has effected been confined solely to the relations that subsist between himself and nature. He has set in motion a series of changes which have reacted on each other in countless circles, both through the organic and the inorganic world. Nor are they confined to the past; they still go on; and, as years roll away, they must produce new modifications and reactions, the stream of change ever widening, carrying with it man himself, from whom it took its rise, and who is yet in no small degree involved in the very revolutions which he originates.

CHAPTER XIX

INFLUENCE OF THE PHYSICAL FEATURES OF SCOTLAND UPON THE PEOPLE

THE connection between the physical features of a country and the history and temperament of its people has hardly received, from either historians or geologists, the attention which it deserves. Though not obtrusive, it is real and close, and amid other and more potent influences has never ceased to play its part in the moulding of national character and progress. It may be seen (1) in the distribution and migration of races; (2) in the historical development of a people; (3) in industrial and commercial progress; and (4) in national temperament and literature. I propose briefly to refer to the illustrations which these questions receive in Scotland.[1]

(1.) The fundamental distinction between highlands and lowlands has had a powerful effect on the wanderings and ultimate grouping of the different races of mankind. Nowhere can the influence of this topographical contrast be better observed than in Scotland. The Scottish Highlands, sharply defined against the Lowland plains, and washed around their other sides by the stormy Atlantic Ocean, offered in rude

[1] A few passages in this chapter have already appeared in an essay on "The Geological Influences which have affected the Course of British History," which is included in my *Geological Sketches at Home and Abroad*, p. 353.

times a wild and almost inaccessible asylum against invasion. There the original Gaelic population has been able to maintain itself, while wave after wave of hostile immigrants has broken against the bases of the hills. The Cymri, who came after the Gaels, possessed themselves of the southern part of the country; but they do not seem ever to have advanced beyond the limits of their Strathclyde territories. The Romans carried their conquests up to the borders of the Highlands, but there was nothing among those dark mountains to invite them farther. They marched into the northern wilds, indeed, but it was rather for vainglory and to punish their savage assailants than with the view of permanent occupation. And so tracing their wall and planting their forts across the narrowest part of the island, they were content to let the Highlanders keep their fastnesses.

When the next wave of conquest brought successive hordes of Norsemen and Danes from beyond the sea to our shores, the same physical features, which had guided and limited the march of the southern invaders, once more set bounds to the progress of the Vikings from the north.

The lowlands of the northern counties and of the Midland Valley lay open to the war-boats of the pirates, and there, driving out or absorbing the Celtic population, the Teutons firmly planted themselves. But they never pushed their way far into the mountains. Down to this day, in spite of the slow but unceasing diffusion and amalgamation of the races, the geological boundary between the rough ground of the crystalline schists on the one hand, and the drift-covered plains of the Moray Firth on the other, is still in great measure the boundary of the Gaelic-speaking and English-speaking populations. On these fertile lowlands, we hear only English spoken, often with a northern accent, or with some northern words that seem to remind us of the Norse blood which flows in the veins of the hardy fisherfolk and farmers. We there come upon groups of villages and towns. The houses, though often

poor and dirty, are for the most part solidly built of hewn stone and mortar, with well-made roofs of thatch, tile, slate, or flagstone. The fuel in ordinary use is coal, brought by sea from the south.

But no sooner do we advance within the Highland districts of the crystalline schists than all the human associations of the ground, as well as its physical aspect, appear changed. Gaelic, though slowly dying out, is still over wide regions the vernacular tongue. There are few or no villages. The houses, built of boulders gathered from the soil, and held together with mere clay or earth, are covered with frail roofs of ferns, straw, or heather, kept down by stone-weighted ropes of the same materials. Fireplaces and chimneys are luxuries not yet universally adopted, and the pungent blue smoke from fires of peat or turf finds its way out by door and window, or beneath the begrimed rafters. The contrast of geological structure and scenery which allowed the Teutonic invaders to drive the older Celtic people from the coast-line, but prevented them from advancing inland, has sufficed during all the subsequent centuries to keep the two races apart.

When Engle and Norsemen landed on the eastern side of the country, the broad selvage of low ground between them and the dark mountains in the distance offered them sites for their new homesteads, which, by degrees, were planted all along the coast within touch of each other. But down the sea-board of the Western Highlands lay no such convenient plain. There the mountains shoot up from the edge of the sea, and though, at the heads of the long, deep, narrow sea-lochs, the salt-water gives place to open, level straths, these cultivable tracts lie so far from the outer coast as practically to form part of the inland country. When the Norsemen sailed down that western coast, they found in it the counterpart of their Scandinavian home—the same type of bare, rocky, island-fringed shores, sweeping up into black mountains, winding into long fjords beneath the shadow of sombre pine forests,

and to the west the familiar sweep of the same wide blue ocean.

The effect of this peculiar configuration—so different from that of the east coast, is curiously marked in the history of the Scandinavian colonisation. Masters of the sea, the Norse Vikings possessed themselves of the Shetland, Orkney, and Western Islands. They likewise held the western sea-board of the mainland. But the want of any continuous selvage of low ground down that coast made it difficult for them to plant there a continuous line of settlements. Only by sea could communication be kept up between the scattered communities. The Norsemen of the west, therefore, remained to the end Vikings—baysmen—familiar with every creek and headland, but never permanently settling in the hilly interior, where the Celtic dalesmen and hardy mountaineers held their ground. Hence, when at last the political connection between Western Scotland and Norway was severed, the Norse population, no longer recruited from its mother country, and hemmed in upon the sea by the near background of mountains, could not maintain its individuality. It was gradually absorbed into the far more abundant Celtic population, which came down again from the interior to the coast. Though the Norsemen held possession of these western tracts for so many centuries, hardly any trace of their former presence is to be detected save in the blue eyes and fair hair of many a Western Highlander, and in the Scandinavian names which still cling to promontory and bay. The relative limits within which the two races dwelt may even yet be approximately traced by the topographical names. Among the islands and along the mere edge of the mainland, abundant Scandinavian words—nishes, nesses, ays, fords, wicks, and many more—remain to remind us of the sea-rovers who brought them. It is in the Orkney and Shetland group, which were farther from the main mass of the Celtic population, and were longer and more completely under Scandinavian rule, that the traces of the Vikings are

most strongly imprinted upon the physical frame and language of the people. To this day a Shetlander speaks of going to Scotland, meaning the mainland, much as a Lowland Scot might talk of visiting England, or an Englishman of crossing to Ireland.

(2.) It is clear, then, that the configuration of the country has been largely instrumental, not only in limiting the distribution of the different races that have peopled the country, but in determining the contrast between the ultimate settlement of the same race on the two sides of the island. But if this influence was so potent in guiding the localisation of the different peoples, we may be sure that it must have been continuously effective in their subsequent political relations to each other. Here, again, the essential difference between the physical features of a mountainous and lowland region must be taken into account as one of the causes that served to protract the long struggle between the Celtic and Teutonic elements in our population. The Scottish Gael has maintained his individuality, mainly because the territory in which he has lived was difficult of access, and seemed to offer little to tempt the Saxon conqueror to invade it. In the end, military roads were driven through his country, chains of forts were built across it, and the wild mountaineer, after centuries of warfare and plunder, was at last subdued. But no serious attempt was made to colonise his wilds with people of an alien race. He has been left in his glen or beside his sea-loch.

It is true, indeed, that during the nineteenth century a steady invasion of his domains has been in progress, which has not left him wholly unaffected. The love of sport and the attractions of Highland scenery have drawn men of another race to these northern wilds. One after another the old Celtic chiefs and lairds have been bought out of their lands by the wealthy Sassenach, who transforms the modest ancestral house into a modern roomy and luxurious shooting-lodge or more ambitious mansion, and spends more gold in his few weeks of residence

than his native predecessors could have done in as many years. But the Highland peasant remains on the soil of his ancestors. His masters have changed, but in the manifold employments of grouse-moor, deer-forest, and salmon-river he finds still the occupations which for ages have been more congenial to him than the drudgery of hand labour.

Again, in the bitter contest that lasted through so many generations between the English-speaking people on the two sides of the Border, the influence of the scenery of the region in which the struggle was waged may be distinctly traced. The march of organised invasion and the path of undisciplined foray were alike determined by the strips of lowland and the passes through the hills, that gave access from the one country to the other. The crags which so greatly diversify the landscape of the Midland Valley were, from early times, the sites of fortified strengths. In the feudal ages these eminences, crowned with the simple massive keep, or with the more imposing castle, became the centres round which the population of each district gathered for mutual protection and assistance. Alike in local feuds and in the struggle for national independence, these fortified crags of Scotland were the heights against which the waves of war beat longest and loudest. At their feet, the clustering huts and booths were the forerunners of the stately streets that now occupy their sites. There can be no doubt that the position of the Scottish capital was determined in remote Celtic times by the easily defensible crag that rises so picturesquely in the midst of the modern city. Other famous sites will at once occur to the reader: Dumbarton, Stirling, Blackness, Dunnottar, Turnberry, Tantallon, Dunbar, and the Bass are familiar names in the stormy annals of Scotland.

This subject might be instructively pursued into detail, with the result of indicating how decisively some of the critical events in the political history of the country have been influenced by topographical feature. As an illustration of this

connection, I may refer to the Battle of Bannockburn.[1] Many travellers who have visited the site of this conflict have felt some difficulty in understanding why the English army, so vastly superior in numbers, did not easily outflank the left wing of the Scots. At present the wide, fertile plain of the Carse, described in the foregoing chapter, stretches for miles to the north and south of the low plateau on which Bruce's forces were drawn up. A small body of the English cavalry did, indeed, make its way across the plain, until overtaken and cut to pieces by Randolph. But why was this force so easily dispersed, and why was no more formidable and persistent effort made by Edward to turn that left flank? It is very clear that had the topography been then what it is now, the Battle of Bannockburn must have had a far other ending.

The true explanation of the difficulty seems to me to be supplied by some almost casual references in Barbour's poem of *The Bruce*, wherein he gives so graphic an account of the battle. I do not mean to contend for the historical veracity of the Archdeacon of Aberdeen, though I think he hardly deserves the condemnation passed upon him by my friend, the late Mr. J. R. Green. As he was born only some two years after the battle, as he had travelled a good deal, and as the field of the conflict lay across the land route from the north to the south of Scotland, we may believe him to have made himself personally acquainted with the ground. At least, he could easily obtain information from many who had themselves been actors in the fight. Now the poet makes Bruce, in addressing his followers, allude to the advantage they would gain should the enemy attempt to pass by the morass beneath them. The narrative goes on to describe the condition of the ground, which was evidently altogether different from what we now see. The modern, fertile, and well-drained plain of the Carse was then a succession of meres

[1] *Macmillan's Magazine*, April 1887.

and bogs, impassable for an army. Barbour tells us how the English tried to surmount these formidable difficulties—

"For in the Kers pulis [pools] thar war,
Housis and thak [thatch] tha brak and bar
To mak briggis [bridges] quhar tha micht pas:
And sum sais yhet the folk that was
In the Castell, qhen nicht can fall
For that tha knew thar mischief all,
Tha went furth ner all that tha war
And duris [doors] and windowis with them bar,
Sa that tha had before the day
Briggit the pulis, sa that tha
War passit our evirilkane [everyone]
And the hard feld on hors has tane,
All redy for to gif battale
Arait intill thar apparale."

We thus learn that Bruce's famous device of the "pots" was only an extension, on the higher and drier ground, of the kind of defence that nature had already provided for him on the lower land to his left. Across the impassable bogs and sheets of water of the Carse the huge army of Edward could not march. It was consequently compelled to crowd its attack into the narrow space between these bogs and the higher grounds on Bruce's right, and lost the advantage of superior numbers.

(3.) The material development of Scotland and the Scottish people offers abundant evidence of the profound influence of geological structure and physical features. Thus the feral ground, or territory left in a state of nature, is strictly defined by the areas of the older rocks, which, rugged and sterile, refuse to come within the limits of cultivation. These territories have ever since the Ice Age been the haunts of wild animals, and they remain so, not, as some crude theorists contend, because the lordly proprietors of the ground have so determined, but because they are fit for neither crops of corn nor herds of sheep. We hear much in these days of the shame

and folly of allowing Highland landlords to keep such wide tracts as game preserves, which might be turned to account in raising food for the people. But the experience of many centuries has shown that these regions are best left in their wild condition. It is a false political economy to attempt to become the master instead of the servant of nature. She has marked out the tracts that can be reclaimed, but has set her seal as indelibly on those that must be left to herself, where her grandeur and her beauty are to remain sacred from the invasions of agriculture or of industry. Man cannot plant crops where she has appointed that they will never grow; nor can he pasture flocks of sheep where she has decreed that only the fox, the wild-cat, and the eagle shall find a home.

It is the lowlands that have mainly contributed to the material prosperity of the country. In these more fertile regions have lain the chief elements of progress. The broad valleys and plains, eroded by the rivers and strewn with the soil carried down from higher grounds, have determined the sites of our principal towns, and the distribution of the great centres and belts of population. Our agricultural progress is the story of lowland farming. Our industrial progress is the story of the exploration of lowland coal-fields and iron-mines. Our commercial progress is the story of the deepening of lowland rivers, the construction of lowland harbours, and the building of the network of lowland railways.

(4.) The influence of the scenery of the country on the national temperament, though less obvious, is probably not less real than some of the more conspicuous relations to which I have referred. I long ago pointed out what seems to me to be an instance of this influence, in the contrast between the Irishman and the Scottish Highlander. So far as they have retained any purity of stock they are both Gaels, originally possessing, doubtless, the same share of the characteristics of their race. But they have been planted amid strikingly different surroundings. The Irishman with the advantages of a mild

climate, a good soil, and a tolerably level country, has been able to live with comparatively little labour. He remains in the holdings where his fathers have dwelt; and so long as he is allowed to stay there, he has no great ambition to push his fortune elsewhere. He has thus retained the natural buoyancy, good humour, and wit of the Celtic nature, with its impulsiveness and excitability, and its want of a keen perception of the claims of duty. In the Highlander, on the other hand, these characteristics have been replaced by a reserved, self-restrained, even somewhat sullen and morose disposition. He is neither merry nor witty, like his cousin across the Irish Channel. Yet he is courteous, dutiful, persevering; a courageous foe, an unwavering ally, whether serving in the ranks or leading his comrades where dangers are thickest. I am disposed to regard this difference in temperament as traceable in great measure to the peculiar condition of the Highlander's environment. Placed in a glen, often narrow and rocky, and separated from his neighbours in the next glens by high ranges of rugged hills, he has had to contend with a scant and stony soil, and a wet, cold, and uncertain climate. He has to wage with the elements a never-ending battle, wherein he is often the loser. The dark mountains, that frown above him, gather around their summits the cloudy screen which keeps the sun from ripening his miserable patch of corn, or rots it with perpetual rains as it lies week after week on the sodden field. He stands among the mountains face to face with nature in her wilder moods. Storm and tempest, mist-wreath and whirlwind, the roar of waterfalls, the rush of swollen streams, the crash of loosened landslips, which he may seem hardly to notice, do not pass without bringing, unconsciously perhaps, to his imagination their ministry of terror. Hence the playful mirthfulness and light-hearted ease of the Celtic temperament have, in his case, been curdled into a stubbornness which may be stolid obstinacy or undaunted perseverance, according to the circumstances which develop it. Like his own granitic hills, he has grown hard

and enduring, not without a tinge of melancholy, suggestive of the sadness that lingers among his wind-swept glens, and that hangs about the birken slopes around his lonely lakes.

But in the formation of the national character, as in the development of the material prosperity of the country, the dominant influence has undoubtedly been that of the lowlands. There, in the earliest and rudest times, lay the widest extent of fertile land to attract and retain the aboriginal settlers. In the subsequent struggle of races, it was there that the battle necessarily raged longest and fiercest. Gael, Cymri, Roman, Dane, Engle, Norseman, all contended on these plains, and there was effected that subsequent fusion of races which has achieved all that is distinctive in Scottish character and history.

The open, defenceless condition of this little strip of territory exposed it to invasion, now from the wild Gaels of the Highlands, now from the devastating English armies. Again and again was it laid waste with fire and sword. It became the battlefield on which the struggle for liberty was fought and won. Its smallness of size kept its people within touch of each other from sea to sea, and engendered, or at least nurtured, that spirit of standing shoulder to shoulder, which is one of the distinctive national traits. And thus, not alone by the contact of man with man, but by the very conditions of the topography, were fostered that ardour of resistance, that stubbornness of purpose, that faculty of self-help, that love of country, that loyalty of Scot to Scot, which through good and evil report have marked off the nation from other men.

If natural scenery has affected national temperament, this influence cannot fail to have made itself manifest in the literature of a country.[1] That it is traceable in the poetry of the different districts of Scotland cannot, I think, be doubted. One of the characteristic features of Highland poetry, and even more, of Highland music, is their melancholy cadence. A

[1] This subject is further developed in my essay on "Types of Scenery and their Influence on Literature," being the Romanes Lecture for 1898.

plaintive wail seems ever to rise as their undertone. Amid all the changes of human feeling and action, we seem to hear the solemn surge of the Atlantic breakers, or the moan of the wind across the desolate moors, or the sigh of the pine-woods, or the dash of the waterfalls and the roar of the floods, as the rain-clouds burst among the glens. We are reminded that the poetry was born among the mountains, that the bards were hunters and cragsmen, familiar with the corries where red deer pasture, and with the precipices where eagles build.

From boyhood I have been familiar with the scenery of the West Highlands, in every aspect of storm and sunshine. I do not mean to stir up the mouldering ashes of the Ossianic controversy, but I have long been convinced that what are called the poems of Ossian had their inspiration from these West Highland scenes. If poetry was to take birth in these regions and to deal largely with outer nature, as well as with human feeling and action, it must have been essentially Ossianic—sad, weird, and solemn. Under the stilted eighteenth-century language, in which Macpherson has given forth his materials, we can descry the kind of thoughts and similes for which the natural surroundings would have prepared us. Many years ago, when through each varying mood of wind and weather, Ossian and my hammer were companions in every ramble among these western moors and sea-lochs, it was strongly borne in upon my mind that, putting Macpherson aside altogether, there is in the poems of Ossian a true poetry of local form and colour, which could only have been created in the West Highlands, but which must be of old date, for it alludes to characteristics that have long passed away. The local truth of the descriptions and allusions is altogether remarkable—the golden sunsets over the western ocean, the surge of the breakers on the dark rocks of the iron-bound shore, the dimpled surface of the Kyle and sea-loch as the breeze sweeps downward from the mountains, the rustle of the bent on the bare moor as the sough of the evening wind passes over it,

the scattered boulders and lonely cairns, the rapid chase of sunshine and shadow as the clouds are driven over firth and fell, the deepening gloom of the gathering storm when the gale howls down the glens, tearing the rain-sheet into long, swiftly following shreds, like troops of dimly seen ghosts. These features are depicted with such simple truth that, whatever may be the value we are disposed to set upon the poetry, we must admit that in Scotland it could only have been born among the West Highlands, and that it is genuine of the soil.

An attempt has been made to find the birthplace of the Scandinavian Eddas in the west of Scotland. The two latest and most learned editors of the northern poetry have indicated many curious points of internal evidence which certainly seem to indicate the influence of a sojourn among the Hebrides, upon the people by whom the Eddas in their present form have been handed down to us.[1] So far as regards geological structure and scenery, the western fringe of Norway and the Hebridean region of Scotland are singularly alike. Hence much of the local colouring of native poetry would be the same in either case. But in Norway, the background of snow-clad, forest-covered mountains makes a fundamental difference in the scenery of the two regions. And I think we can trace the influence of this difference so certainly in the Eddaic poems as to warrant the conviction that originally these compositions had their birth in the Scandinavian north, but could not have arisen in Scotland; and that any traces of Hebridean influence must be due to the effects of a prolonged sojourn in the north-west Highlands upon a people who brought their ballads and songs with them from the north. I cannot believe that the mythology of Odin and Thor, of the Frost Giants, the Mud Giants, the Rock Giants, the Wind Giants, of Nifelheim and Muspelheim, the regions of torrid heat and of snow and ice, could ever have been conceived among the Western Islands of

[1] *Corpus Poeticum Boreale, the Poetry of the old Northern Tongue*, by Gudbrand Vigfusson and F. York Powell. 2 vols. Oxford, 1883.

Scotland. Neither the scenery nor the climate would suggest them there. But, on the other hand, they are just the conceptions that might be inspired by the rugged mountains, the snow-fields and glaciers, the brief hot summers and the long, dark, chilly winters, the storms, avalanches, landslips, and waterfalls of the Sogne and the Hardanger, and the earthquakes, volcanoes, and geysirs of Iceland.

Again, the well-known contrast in style and treatment between the northern and southern ballads in our national poetry seems to me to lead us back to the fundamental distinctions between the physical features of the Border country and those of more southern and civilised parts of England. The northern ballad glows with poetic fire, whether the subject be border raid, or deed of chivalry, or tale of tragic love, or weird enchantment of fairy or warlock. We feel the keen northern air breathing through every line. The varied scenery of that wild Border land forms the background of the scenery in the poems, and according to their theme, we find ourselves among rough moss-hags or in fertile dale, on bare moorland or sheltered cleugh, by forest-side or river-ford, amid the tender green of birken shaws or the sad russet of dowie dens. The touches are lightly given, but they constitute one of the great charms of the poems. In the southern ballad, on the other hand, the local colouring is absent, or at least is so feeble that it could not have had the dominant influence which it exercised upon the imagination of the northern minstrels. The versification falls into what Hallam has justly called "a creeping style which has exposed the common ballad to contempt." To my mind, this tame featureless character is suggestive of the sluggish streams, and pleasing but unimpressive landscapes, amid which the southern minstrels sang.

In fine, if we attempt to analyse the impression which the scenery of a long-inhabited region makes upon our minds, we can trace the working of more complex influences than might at first appear. The public taste has at length been

educated to appreciate the variety of nature. Mountains are no longer described with horror, but are sought with even more determination than they were formerly avoided. In looking at Scottish landscapes, however, it is not merely the external forms that fill the eye. There is almost always some human element in them that blends with the natural features, sometimes so subdued as to be hardly appreciable, but at other times glowing with such vividness as even to rival in power of fascination some of the more impressive aspects of nature, or to add fresh tenderness and grace to what nature has herself made supremely tender and graceful. Who, for example, does not recognise amid the wilds of Glencoe, that there hangs over that dark defile a deeper gloom than was ever woven out of the grey mists of heaven and the sombre shadows of the mountains? Or who that knows the history and traditions of Yarrow can wander along that valley without feeling that the green hillsides and plaintive stream are bright, not merely with sunshine, but with the halo of bygone human love and sorrow, and re-echo, above the sounds of to-day, the songs of generations long since at rest?

At no time in our history as a nation has the scenery of the land we live in been so intelligently appreciated as it is to-day. Never were its varying aspects so familiar to so large a part of the community, which can now travel with ease into the remotest nooks and corners of the country. We have only to walk through a modern picture-gallery, or to read a recent volume of poetry, or to take up the last novel, to perceive how deeply the influence of landscape has affected the imagination of our time. And yet, on the other hand, never did so large a proportion of the population live and die pent up within narrow gloomy streets, whence all that is seen of outer nature is the sky overhead, to whom a sweep of green valley and breezy upland, or a range of crag and mountain, is so unknown that its existence can hardly be realised. A large and rapidly increasing section of the people is thus removed from contact

with landscape, and from all the pleasurable and healthful influences which that contact affords. We may not be able to forecast the future; but we should at least recognise that, in the past, it is the influence of external nature which has, in no small measure, helped to mould our national character. The physical features of the country, the soil, the mineral products underneath, have all directly or indirectly told upon our temperament and progress. The love of country, therefore, should not be with us a mere sentimental feeling, but a genuine enthusiasm springing from a conviction that for much that is worthiest in us as a people, we are indebted to those rolling lowlands and rugged hills which, from generation to generation, have caught for us the light and the gloom of heaven.

CHAPTER XX

RECAPITULATION AND CONCLUSION

A BRIEF summary of the principal conclusions to which an examination of the superficial features of Scotland leads may fitly conclude this volume. In any investigation of this kind, there are always two lines of research which must be kept quite distinct—the history of the rocks and that of the configuration which they present at the surface. Each hill and valley, each mountain and glen, has thus a twofold story. There is first the record of the formation of its component rocks, whether these have been laid down layer after layer as sand, gravel, or mud upon the bottom of a former sea, or piled up as shingle along an ancient beach, or drifted as ooze over the bed of a lake; whether formed of the decay of extinct forests, or from the gathered fragments of corals and shells; whether rolled along in the form of liquid lava, or thrown up in showers of volcanic dust and ashes. After we have tried to trace out the succession of events imperfectly chronicled in the rocks, there remains the story of those after-changes, whereby the various accumulations that had been piled over each other, and had sunk down for thousands of feet, were fractured, folded, and once more upheaved above the level of the sea into the aboriginal land, from which the existing land has descended. And lastly, there is the story of the gradual carving of that upheaved land into valley and hill, and the evolution of the topography which is now to be seen.

The hills and valleys of Scotland are obviously not all of one age. They differ greatly also in geological structure, with a corresponding variety of scenery. As a convenient subdivision they were grouped into three districts,—the Highlands, the Southern Uplands, and the Midland Valley. In taking leave of them, however, for the present, let us regard them finally as a whole, and picture briefly the changes by which they have come at last to wear their present outlines.

Abundant as is the evidence of vast subterranean disturbance, it is assuredly not to that cause that the origin of the existing topography of Scotland is to be assigned. Huge masses of rock, torn from a depth of at least two or three thousand feet, have undoubtedly been driven upward and pushed along for miles. The crust of the earth has been fractured in innumerable places, and the severed sides of the fissures have been uplifted or depressed for many hundred feet. Mountainous masses of eruptive material have been thrust into the rocky crust, disrupting and altering the surrounding rocks. All this and more has taken place; and yet, paradoxical as it may seem, we are driven by the actual evidence of the present surface to conclude that these colossal movements have not determined the existing topography. It is not even certain that they ever affected the surface. They were probably in most cases deep-seated, and if they proceeded slowly, any uplift which they might cause at the surface may have been removed by denudation as fast as it rose. But in any case, it is quite certain that the present topographical features were not determined until the effect of these ancient disturbances had been levelled down by denudation.

We have seen that this denudation has been in progress since early geological time. The very stratified rocks that form most of the framework of the country are the most striking monument of this waste, for they have been derived from the degradation of adjoining land. We know that the rocks of the Highlands and Southern Uplands had been enormously

planed down before the deposition of the Old Red Sandstone; that the Old Red Sandstone was in turn upraised and extensively abraded before the formation of the Carboniferous strata; that these again were greatly eroded before they were covered with the Permian sandstones. But perhaps the most astonishing proofs of waste are those supplied by the basalt plateaux and dykes, which prove that even since older Tertiary time a thickness of many hundreds of feet of rock has been stripped off the surface of the country.

In describing the cause of this stupendous waste, I have spoken of it as a kind of land-sculpture, and the denuding agents as tools employed by nature in the task of chiselling out the valleys and carving the hills into their present forms. Air, rain, springs, frost, rivers, glaciers, and the sea have all in turn been employed, and each has left its own impress upon the landscape.

The land may have been again and again worn down to the level of the sea, and finally planed away by the waves, until it reached a base-level of erosion beneath the limits of breaker-action. Such an eroded surface seems still traceable in the table-lands of the Highlands and Southern Uplands. On its upheaval once more into land, the denuding agents would at once begin to play upon it. Rain falling on the upraised surface would find its way from the centre by devious paths outwards and downwards to the shore. These paths, once chosen, would be deepened and widened, until the table-lands, like a sandy beach on the recession of the tide, were hollowed out into a system of valleys, every shower of rain, every spring, every frost, every stream contributing its share in the general waste.

Hutton and Playfair long ago showed what an admirable relation of size and direction is maintained between the streams and the valleys in which they flow, and proved that this relation can only be explained on the supposition that the valleys were excavated by the streams. The frequent want of connection

between the trend of the valleys and the geological structure of the ground which they traverse, probably indicates that this trend was determined before the rocks now visible at the surface influenced, as they at present do, the superficial topography. In many cases, the valleys appear to have been first traced out upon overlying formations which have since been denuded away. The watershed is in this respect of great significance, serving to indicate where the drainage was or was not influenced by the geological structure of the rocks now forming the surface, and thus helping still further to impress upon us the vastness of the denudation of the country.

In one of the latest geological periods, known as the Ice Age, nature made use of a sculpture-tool no longer to be seen at work in Britain. When the present valleys and hills had been long in existence, the climate gradually became arctic in character, and sheets of snow and ice settled down upon the country. As in Greenland at the present time, an ice-sheet covered the whole of Scotland, and moved seaward in vast icy streams. Creeping over the land for a protracted period, it ground down its surface, removing the angular forms left by the previous sub-aërial waste, and replacing it by the smooth, polished, and striated surface so characteristic of glacier-friction. A large amount of detritus was spread over the low grounds and slopes of the hills as boulder-clay. Huge blocks of rock were likewise borne far away from their native mountains, and dropped upon the hill-tops and plains of the lowlands.

Since the ice melted away, the sea, rains, streams, springs, and frosts have renewed their old work of demolition. The smoothed and flowing outline which the ice left behind it is now undergoing a slow destruction, and the rocks are quietly resuming the rugged outlines which they had of old. The sea-coasts are receding before the onward march of the waves. Former ravines have been deepened and widened by the rivers, and new ones have been formed. Man, too, has come upon the scene, and has set his mark upon well-nigh every rood of

the land from mountain-top to seashore. He has helped to demolish the ancient forests; he has drained innumerable lakes, fens, and mosses, and turned them into fertile fields; he has extirpated the wild beasts of the old woods, thus changing both the aspect of the country and the distribution of its plants and animals. He has engraved the land with thousands of roads and railways, strewn it with villages and hamlets, and dotted it with cities and towns. And thus more has been done by him, in altering the aspect of the island, than has been achieved, during the brief period of his sojourn, by all the geological agencies put together.

Such in outline is the explanation which I have proposed for the origin of the present scenery of Scotland. It is based upon observation of the geological structure of the ground, combined with an examination of the amount and results of denudation. It puts aside, as mere figments, the crude notions formerly in vogue as to Titanic convulsions that shaped the land into its present form. It is based, as far as possible, on actually ascertained fact and measurement, and on what is known to be the order of nature now, rather than upon speculation as to what it may have been. The brief recorded experience of man cannot, it is true, be taken as a standard by which past time is in everything to be measured. But it is vain to feign causes which cannot be shown to have existed except by the evidence which they are invented to explain. It is not only safer, but it seems the only philosophical course, to interpret the past changes of the earth's history by constant reference to what experience shows us to be the actual mode of nature's working now. And that the various processes at present engaged in altering the surface of the globe are enough to have given rise to all the varieties of scenery in these islands must, I believe, be admitted by every one who has realised what they are busy doing, and the rate at which they work. But while it appears to me certain that our scenery has been carved out by the same agencies of denudation that are still

carrying on the task to-day, there is no proof that the rate of waste has always been the same. There may have been periods when the activity of rain and frost, for instance, was greater than now, and when, in consequence, the general waste of the land was more rapid. Hence, to take the present rate of waste as the standard for all past time may be to fix the estimate too low.

But, even with this limitation, we cannot contemplate the present landscapes of our country as the result of a slow and unequal decay without being impressed with a sense of the vastness of the time which is demanded. Even though the geologist has learnt from modern physics that he has no longer the unlimited bank of time at his command, on which he was wont to make such exorbitant and reckless drafts; the periods with which he has still to deal are vast enough to baffle our imagination adequately to realise them. In this dim, shadowy antiquity, so impressive from its immensity, and from the slow and stately march of the events which it witnessed, there is surely an ample equivalent for the grandeur of the Titanic upthrows which were once the easy solution of the problems of topography. There was, no doubt, a certain mental excitement in contrasting the peace and quiet of the living world with what seemed the records of fierce cataclysms in earlier times; in turning from the fair meadows and corn-fields of the lowlands to the crags that were believed to have been heaved into the air when the earth was shaking and tossing like a storm-vexed sea; in listening to the ripple of the river, and reflecting that the tree-shaded ravine in which it flows was rent asunder by some primeval earthquake. But surely the lover of natural scenery is furnished not less amply with material for suggestive meditation when he learns to recognise everywhere the proofs of slow imperceptible change, which, ceaselessly advancing through the ages, comes at last to attain the most colossal dimensions; and when, deeply impressed with the magnitude of this waste, he follows its march over cliff and precipice,

corry and ravine, upon the crests and summits of the mountains, in the depths of the valleys, and by the margin of the sea.

The story of the origin of our scenery, as thus interpreted, is of a piece with the rest of the teachings of nature. It leads us back into the past farther than imagination can well follow, and, with an impressiveness which we sometimes can hardly endure, points out the antiquity of our globe. It shows that in the grander revolutions of the world, as well as in the humbler routine of everyday life, it is the little changes which by their cumulative effects bring about the greatest results; that the lowly offices of wind and rain, springs and frosts, snow and ice, trifling as they may appear, have nevertheless been chosen as instruments to carve the giant framework of the mountains; and that these seemingly feeble agents have yet been able, in the long lapse of ages, to produce the widest diversity of scenery; and to do this, not with the havoc and ruin of earthquake and convulsion, but with a nicely balanced harmony and order, forming out of the very waste of the land a kindly soil, which bears, year by year, its mantle of green, yielding food to the beast of the field and the fowl of the air, and ministering to the wants and the enjoyment of man.

APPENDIX

ITINERARY

A BRIEF summary of the more obvious or interesting geological features, in their relation to scenery, which lie open to the observation of the traveller by some of the principal routes through Scotland, and more especially of those to which allusion is made in the foregoing chapters, may make this volume more useful to the general reader. I have accordingly prepared the following notes, in which the figures placed within square brackets refer to the pages where fuller information will be found regarding the rocks or topography.

The Maps which accompany this volume are on a scale sufficiently large to show the broader features of the topography and geological structure of the country. For the purposes of the traveller and the student, more detail will be found in the Geological Map of Scotland, on the scale of ten miles to an inch, prepared from the work of the Geological Survey and published by Mr. Bartholomew of Edinburgh. Those who desire a still larger amount of information will find it on the maps of the Geological Survey, which are published on the scale of one inch to a mile. In the following descriptions of routes in Scotland reference is made to these maps as Sheets so far as they are yet published, each of them being distinguished by its number in the consecutive series into which the whole map of the country is divided.

Scotland is usually approached by railway from the south; less frequently by steamer into the Clyde or into the Forth. On the eastern side the only railway approach is by Berwick. On the western side there are three routes into the country, but they all diverge from the single station of Carlisle. The intervening region is mainly occupied by the high uplands of the Cheviot

Hills, but a line of railway has been carried through these uplands from Newcastle by the valley of the North Tyne to Riccarton Junction, where it joins one of the routes from Carlisle.

1. East Coast Route

Berwick to Edinburgh

(Sheets 34, 33, and 32 of the Geological Survey map of Scotland[1])

Berwick is a good centre for the exploration of the coast sections of the Southern Uplands [309] and the broad lowland or Merse [335], which, spreading out between these uplands and the base of the Cheviot Hills, forms the lower part of the valley of the Tweed. The southern horizon is bounded by the line of the Cheviots (2668 feet). Along the western sky-line the plain terminates in the range of low volcanic ridges of which the most prominent is crowned with Hume Castle [362], a conspicuous object in the south-east of Scotland. To the north-west and north, the long line of featureless high ground is the edge of the Southern Uplands [310]. The most interesting scenery in the immediate neighbourhood of Berwick is to be found along the coast, which for some twenty miles to the north presents an almost continuous line of bold sea-precipices [54]. For the first five miles the cliffs are formed of reddish Carboniferous sandstone, and furnish excellent examples of the characteristic features of that rock. At Burnmouth the greywacke and shale of the Silurian series set in, and continue in a remarkably picturesque range of precipices, stacks, skerries, and caves as far as Eyemouth. Some of the plications of the strata are admirably exposed [55, 311]. From Eyemouth to beyond Coldingham the coast is less precipitous and more indented with bays and low shores, where the volcanic rocks of the Lower Old Red Sandstone and altered Silurian strata, traversed by felsite veins, are displayed. At St. Abb's Head [54, 55] a mass of dark volcanic rocks projects

[1] The numbers of the Sheets of the Geological Survey map of Scotland are arranged at the beginning of each route in the order in which the districts shown on the map are traversed and described in the Itinerary. The surroundings of Berwick on the English side of the Border are given in the map of England, Sheet 110, Old Series, in four quarter-sheets, which are numbered 1, 2, 3, and 4 in the New Series. An account of the geology on the Scots side is given in the Memoir on Eastern Berwickshire to accompany Sheet 34 of the map of Scotland, while that on the English side will be found in the Sheet-Memoirs descriptive of the quarter-sheets of Sheet 110 (Berwick, Norham, Wooler).

beyond the rest of the coast-line, and bears the lighthouse. From this headland a continuous range of noble precipices—the highest on the east side of Scotland, for they reach a height of 500 feet above the sea—stretches westward for five miles. Nowhere are the foldings of the Silurian strata more magnificently laid bare. The cliffs present a succession of gigantic arches and troughs wherein the massive beds of greywacke are folded like piles of carpets [Figs. 16, 84]. To the geologist also there is a special interest in the beautiful unconformable junction of Old Red Sandstone at Siccar Point, on account of the deductions drawn from it, in the infancy of geology, by Hutton, Playfair, and Hall, with regard to the geological history of the earth [55].

Inland excursions from Berwick may be made to (1) the **Cheviot Hills**,[1] which are best reached from Coldstream either by the valley of the Beaumont Water or that of the Kale; at the head of the former stream small moraines show that local glaciers remained there after the retreat of the ice-sheet; (2) **Kelso** and **Jedburgh** (Sheets 26, 25, 17), where the characteristic differences of feature between the stratified rocks (Upper Old Red Sandstone and Carboniferous) and their associated igneous masses are well seen. The more conspicuous hills, such as Peniel Heugh, Dunian Hill, Bonchester Hill, and Rubers Law [316, 338], are all hard, igneous masses, from which the surrounding and overlying stratified rocks have been worn away; some of them are volcanic necks or the roots of old volcanoes (north end of Lanton Hill, Black Law, Watch Knowe, part of Rubers Law and the Minto Hills); (3) **Duns** and **Greenlaw** (Sheets 33, 25); from Duns Law, also a projecting igneous mass, an extensive view is obtained of the whole Merse up to the Cheviots, while the range of the Southern Uplands rises immediately behind. The valley of the Whiteadder is a characteristic sample of the valleys in these uplands. To the west of Duns the best group of kames [344, 400] in the south of Scotland is to be seen, between two and three miles north of Greenlaw, on the north side of Dogden Moss (Sheet 25).

Berwick to Edinburgh.—Glimpses of the coast cliffs are here and there obtainable from the railway carriage between Berwick and Burnmouth.[2] Approaching Ayton, the line bends away to west, and affords a view of the eastern end of the Lammermuir Hills [309] rising above the low grounds of Berwickshire. It enters these hills beyond Reston Station, following the

[1] See *Geol. Surv. Memoir* on Cheviot Hills, by C. T. Clough.

[2] "Geology of Eastern Berwickshire," *Mem. Geol. Survey.*

line of the Eye Water. The railway cuttings show the highly-inclined greywacke and shale of the Silurian uplands. About four miles north from Grant's House Station the line emerges from the Lammermuirs, and crosses a series of picturesque ravines which have been cut by small streams in the Upper Old Red Sandstone and Lower Carboniferous rocks. The defile of the Pease Burn is a deep, narrow gorge, which was formerly one of the easily defensible obstacles to the progress of an advancing army. To the right lies the fishing village of Cove, with its sandstone cliffs [56], and beyond it, as the train moves on, the whole range of cliffs may be seen to the right, eastward as far as the promontory of Fast Castle. To the left the smooth slopes of the Lammermuir Hills rise steeply above the plain which widens toward the west. **Dunbar**, with its castle and cliffs of volcanic tuff [56, 335], offers many points of interest to the geologist.[1] Out to sea the May Island, one of the numerous sills in the Carboniferous formations of the basin of the Firth of Forth, surmounted with its lighthouse, may be seen lying at the entrance to the estuary. The summit of the Bass Rock [363, 383, 384, 431] is a conspicuous object on the right. In the bed of the Tyne at East Linton, and also in the railway cuttings there, the traveller will see some of the andesite lavas of the Lower Carboniferous volcanic series of the Garlton Hills, and farther on in front of him to the left hand he will remark the top of Traprain Law [382], another of the volcanic "necks" of this region. He is now in the midst of one of the volcanic areas of the Lower Carboniferous system of the Midland Valley [357]. The heights to the left, with the Hopetoun Monument on their summit, are the Garlton Hills, composed of trachytic lavas and tuffs, while the striking cone which rises close to the sea on the right, and is visible for some miles of the journey, marks another volcanic vent known as North Berwick Law. On the farther side of the Firth of Forth, the hills of Fife come into view, with the lighthouse-crowned island of Inchkeith in front of them. As the train enters Mid-lothian, Arthur's Seat rises boldly in front, and the chain of the Pentland Hills appears beyond to the left. At last, sweeping past the base of the crags of the former eminence, the traveller enters a tunnel cut through the Lower Carboniferous volcanic rocks of the Calton Hill, and, skirting the foot of the precipice on which the jail is built, finds himself in the valley that divides the Old and the New Town of Edinburgh.

[1] This district is described in the "Geology of East Lothian," *Mem. Geol. Survey*.

2. Waverley Route

Carlisle to Edinburgh by Hawick and Melrose

(Sheets 11, 17, 25, 33, 32[1])

This route affords the longest and most varied traverse of the Southern Uplands. Like Berwick, on the eastern side, **Carlisle** is a convenient centre for the exploration of the scenery and geology of a large region of the Scottish border. It commands lines of railway that lead the visitor into Nithsdale, Annandale, Eskdale, Liddesdale, and other valleys. With one exception—that of the branch railway to Langholm—these are through-lines, and the features to be seen in journeying by them will be described in the account of the different routes into Scotland from Carlisle.

After quitting Carlisle the railway turns away to the north-east, and crossing a drift-covered and peaty plain, enters the Triassic district of Southern Dumfriesshire. Where the Esk and Liddel join, a branch railway runs up the lower part of Eskdale as far as **Langholm.** The geologist who has time at his disposal will be rewarded by making Langholm his headquarters for two or three days. From that centre he can ascend the valley of the Esk (Sheets 11, 10, 16) and see some of the characteristic features of the opener depressions in the Southern Uplands. In that valley also, near the parish church of Eskdalemuir, he will find, on the left side of the road, one of the best examples of the outcrop of a great Tertiary dyke [336, 339]. The rock, which is partly a basalt-glass, forms a conspicuous crag crowning the hill of Wat Carrick. This dyke can be traced south-eastward into England and north-westward beyond the Leadhills, a total distance of 45 miles. More striking is the scenery of the Ewes Water [310, 313, 338, 362]. The great escarpment of volcanic rocks at the base of the Carboniferous system runs from Annandale through Birrenswark [312, 338, 362] to Langholm, whence, much shifted by faults, it bends northward, and rising in altitude as it proceeds, attains in Pike Fell [338], Arkleton Hill, and the Pikes heights of from 1600 to upwards of 1700 feet. There are few more interesting walks in the south of Scotland than from Langholm, along the range of this escarpment, to the head of the Hermitage Water, and thence back by the scattered "necks" on the west side of Liddesdale, which mark the sites of volcanic

[1] The geology of the English side of the Border around Carlisle will be found in Sheets 106, 107, 101, and 102 of the map of England.

vents of Lower Carboniferous age [338]. The old coach-road up Ewes Water crosses the watershed at a height of about 800 feet by the Mosspaul Pass, which leads down into Teviotdale. The valley is much narrower and the hills are loftier than in Eskdale.

The River **Liddel**, a little above its junction with the Esk, has cut a picturesque ravine in the Carboniferous Limestone series at Penton Linns. The high grounds on the left, as the train moves up Liddesdale, are formed by the dip-slope of the lavas of the great volcanic escarpment. The small, green conical eminences on the lower slopes mark the positions of some of the volcanic vents above referred to, the most conspicuous being the Tinnis Hill, opposite Kershopefoot Station [338]. The long ridge to the right, forming the boundary of the valley on that side, is capped with a group of white and yellow sandstones, the escarpments of which form a marked feature far over into the English border. At **Riccarton** Junction, where the railway from the North Tyne joins the main line, a section is laid open of the long Upper Silurian ridge of Arnton Fell, which separates the valleys of the Liddel and Hermitage Water. But Carboniferous rocks appear again immediately on the north side, and are seen in the cuttings before the train enters the tunnel, which here pierces the ridge that forms the watershed of the country. The high detached conical eminences to the left (Maiden Paps, 1677 feet; Great Moor, 1964 feet) are volcanic vents and bosses connected with the great escarpment [338]. The high hill to the right, before reaching Shankend Station, is Windburgh Fell (1662 feet), which belongs to a volcanic zone that was erupted after the Birrenswark and Arkleton band, during an early part of the Carboniferous period. This zone of lavas and tuffs can be traced in detached outcrops from the west side of Eskdale all up Liddesdale, and it attains its chief development about Windburgh Fell. Owing, however, to a large fault which brings down the younger formations against the Upper Silurian rocks, it is abruptly cut off here, and is not seen farther north.

The railway now rapidly descends the valley of the Slitrig, among Silurian rocks and thick accumulations of boulder-clay. At **Hawick** it enters Teviotdale close to the line of another of the great east and west Tertiary dykes which strikes eastward through the Cheviot Hills. The glaciation of this district is remarkably interesting, the exposed bosses of rock being ground smooth and striated in a general north-easterly direction [342].[1]

[1] The peculiar glaciated topography of this region, with the ridges of ice-moulded rock and drums of boulder-clay all directed towards the north-east, is

As already stated, Minto Crags on the right hand, the loftier hill of Rubers Law on the opposite side of the Teviot, and some other detached eminences between the line of railway and Ancrum, mark volcanic vents of the district [338]. Other prominent isolated hills, which appear to the right as the train moves northward, are intrusive masses of diabase in the Upper Old Red Sandstone, and beyond these rises the line of the Cheviot Hills.

Approaching **Melrose** the visitor is brought in sight of other conical volcanic hills. The loftiest of these form the group of the Eildon Hills, along the base of which the line of railway runs [316, 335, 338, 402]. Immediately to the south of the village of Melrose lies the site of the largest volcanic vent in the district. It is filled with agglomerate and tuff, forming a range about a mile and a half in length and three-quarters of a mile in breadth. For a few miles the journey lies in the valley of the Tweed, but this river is crossed a little beyond Melrose, and the railway then ascends the Gala Water—a thoroughly characteristic valley of the Southern Uplands. The left side is more thickly covered with boulder-clay, while on the right side the successive craggy hillsides mark the outcrop of the bands of harder grit [342].

The watershed of the country is crossed at a height of about 900 feet. After it is passed the railway soon bends north-westward out of the Southern Uplands into the Carboniferous region of the Midland Valley. Deep accumulations of boulder-clay may be seen in the hollows on either side. As the train advances, a good view is obtained of the whole chain of the Pentland Hills lying to the west and in front. The more featureless southern parts of this chain consist of conglomerate, while the conical eminences of the central and northern parts have been carved out of the volcanic rocks of the Lower Old Red Sandstone [367, 369]. At length the lion-shaped Arthur's Seat comes into sight, and the old town of Edinburgh, with the Castle Rock at its western end. Making a wide sweep to near the coast, the line turns westward, and passing between Arthur's Seat and the Calton Hill, reaches the Waverley Station in the heart of Edinburgh [384].

well delineated on the shaded one-inch Ordnance or Geological Survey maps (see in particular Sheets 17 and 25).

3. West Coast Route

Carlisle to Edinburgh by Beattock and Carstairs

(Sheets 10, 16, 15, 23, 32)

In leaving Carlisle, the train crosses the Triassic plain of the Eden, and turns to the north-west across the drift-covered low grounds that border the Solway Firth. Much of this plain was formerly covered with peat, and even yet, in spite of the progress of agriculture, large remnants of the famous "Solway Moss" are still to be seen. The small streams, crossed by the railway, have cut deep ravines in the red Triassic and Lower Carboniferous strata, as well as in the overlying drift. Numerous boulders of grey granite, scattered about the surface, show that the ice which transported them came eastwards from Galloway. The most conspicuous hill to the right is Birrenswark—a portion of the great escarpment of volcanic rocks which here lie at the base of the Carboniferous system [312, 338, 362]. Below these rocks lie the highly inclined and convoluted Silurian greywacke and shale of the Southern Uplands, which are entered to the south of **Lockerbie.** Representatives of the Ludlow and Wenlock groups are seen in the cuttings beyond Lockerbie Station. A little farther north, the line of railway passes into the old Permian valley which was the forerunner of the present valley of Annandale [313, 331, 336-339]. No sections of the Permian sandstones are to be seen from the train, for the whole plain through which the River Annan winds is deeply covered with drift, much of which is arranged in groups of kames. The famous quarries of Corncocklemuir, from which so many Permian labyrinthodont footprints have been obtained, lie a few miles to the west.

From **Beattock** Junction a good view is obtained of some of the higher parts of the Southern Uplands.[1] To the west or left hand the highest eminence visible for a long way from the south is Queensberry Hill (2285 feet), which owes its prominence and more rugged surface to the hard massive bands of grit of which it is composed [337]. Due north from Beattock the highest summit visible is that of Hart Fell (2651 feet) [317]. The scenery of Moffatdale and the head of Annandale is more particularly referred to on pp. 472, 473.

To the north of Beattock the railway ascends the valley of

[1] The geology of this region will be found fully described in the *Geological Survey Memoir* on the Silurian Rocks of Scotland, by Messrs. Peach and Horne, 1899.

the Evan Water, through a series of cuttings in the Upper Silurian (Llandovery) rocks, until it reaches the watershed of the country at a height of a little over 1000 feet. Mounds of rubbish, with hollows filled with peat, here mark the sites of former glaciers in these uplands. The long smooth slopes at the bases of the hills show the position of the boulder-clay that forms so conspicuous a platform along the floors of the valleys [342]. The traveller is now in Clydesdale, and, as the engine quickens its pace in descending the valley, he can mark how the infant Clyde is rapidly augmented by innumerable streams from the high grounds on either side. Before passing **Elvanfoot**, near which the Lower Silurian series is entered, he can see, up to the left, the huge, swelling, smooth-sloped Lowther Hills [317, 337] up the valley of the Powtrail Water. Farther to the north the most interesting feature in the route is supplied by the two great Tertiary dykes which cross the valley of the Clyde, one a little to the north of Elvanfoot, the other a little north of Abington. Neither of them makes any prominent landmark on the hillsides, but they are of great importance in showing how much the valley-system of the country has been worked out since Tertiary time [166, 336, 339]. Between **Abington** and **Lamington** the line bends away to the north-east and crosses the great boundary fault which defines the northern margin of the Southern Uplands. To the right hand, the eye can follow for some miles to the north-east the steep face of these uplands. To the left, the beautiful conical hill which rises on the north side of the valley is Tinto (2335 feet), which consists of a mass of flesh-coloured felsite intruded into the Lower Old Red Sandstone [362, 376, 378, 381].

From **Symington** Junction the traveller looks to the right, eastward across the low watershed separating the Clyde and Tweed [378], and can now see, looking back towards the south, the smooth Lower Silurian heights of Culter Fell and the range of uplands that sweep away towards the north-east. The lower hills to the right between Lamington and Symington are formed of lavas intercalated in the Lower Old Red Sandstone. At Symington and thence northward to Carstairs many admirable examples of kames are to be seen [402]; one in particular may be observed to have been cut through by the Clyde, near the conspicuous felsite cone of Quothquan on the right bank of the river [381]. The wide alluvial plain, which the Clyde has levelled out among these sandy and gravelly deposits, is best seen where the railway crosses the river for the last time, just before reaching Carstairs Junction.

The railway north-eastwards from **Carstairs** passes through a tract of peat-mosses and kames [402, 403]. From Cobbinshaw Reservoir a good view is obtained of the Pentland Hills to the right. The most southerly eminences in that chain are the East and West Cairn Hills (1839, 1750 feet), formed of gently inclined Upper Old Red Sandstone, with the deep gap of the Cauldstane Slap between them. A little farther on, the more conical eminences of the chain formed of the andesites, orthophyres, diabases, and tuffs of the Lower Old Red Sandstone rise along the sky-line and continue to bound the view on that side during the rest of the journey. To the left the eye can sweep over a wide tract of the Midland Valley. The isolated volcanic hills of Linlithgowshire are the most prominent objects, especially Binny Craig, which is distinguished by its abrupt western face and gentle eastern slope [362, 384, and Fig. 104]. Beyond these, if the weather be clear, the traveller can see the whole panorama of Lowland topography, from the hills of Fife through the long line of the Ochil Hills, westwards to the Trossach Mountains, with their tops peering into the clouds far to the left. In front occasional curves of the line allow glimpses to be had of Edinburgh and Arthur's Seat, and the train finally comes to a stand in front of the precipitous crag on which Edinburgh Castle is perched.

4. West Coast Route

To Glasgow by Carstairs

(Sheets 23, 31)

The greater portion of this journey has already been described at p. 456. At **Carstairs** the Glasgow and Edinburgh portions of the train are separated. The route westward first skirts a remarkable district of kames [403], which are best seen to the west and north of the village of Carstairs. It crosses the Mouse Water a little above the deep ravine by which that stream joins the Clyde [379, 403], and then strikes into the coalfield of Lanarkshire, keeping on the whole parallel with the Clyde, but at a distance of two or three miles. The coal-workings around Motherwell and Wishaw have revealed under the boulder-clay, which here spreads all over the country, two ancient buried river channels, probably those of the South Calder River and Tillon Burn. The post-glacial ravine of the latter stream underlies the railway about a mile beyond Motherwell Junction. The Clyde is

crossed a little below the ravines of Bothwell [380], and the railway then runs along or close to the edge of a terrace of erosion in the glacial deposits at a height of about 100 feet above the sea [400]. Below this platform of the 100-feet beach lie the modern alluvial terraces of the Clyde.

5. West Coast Route

To Glasgow by Dumfries and Kilmarnock

(Sheets 6, 9, 15, 14, 22, 30, 31)

Crossing the low, drift-covered plain referred to at p. 453, the traveller enters Scotland near **Gretna Green**, the boundary between the two countries being the River Sark. Looking to the left, across the Solway Firth, he may see in the distance Skiddaw, and other hills of the Lake District. To the west, in front of him, the most conspicuous eminence is Criffel, a mass of granite which, rising from the mouth of the Nith to a height of 1867 feet, forms the most easterly of the hills of Galloway. The flat ground between the railway and the Solway lies on a group of raised beaches, of which the 25-feet terrace covers most of the ground, though here and there the 50-feet platform is also seen. At Annan a branch line from the Caledonian Railway at Kirtlebridge Station crosses the Solway Firth for Maryport and Whitehaven, and affords at low water a good view of the wide tracts of sediment brought down by the Annan, Sark, Esk, Eden, Wampool, and Waver, and deposited in the upper reaches of the estuary. Beyond **Annan** Station the railway crosses the River Annan, which enters the Solway between mounds of gravel, raised beaches, and terraces of its own alluvium. The opener part of the Firth and the mass of Criffel are better seen as the train moves westward, until the railway turns inland towards the north-west, and skirts the Lochar Moss, the largest tract of peat in the south of Scotland [418]. The ridge on the west side of the Moss is formed of Permian breccia. Crossing the Moss, where it contracts to about a mile in width, the railway line strikes into Dumfries.

Dumfries is a good starting-point for Galloway (p. 483). From this halting-place the journey is pursued up Nithsdale, which, like Annandale, is an ancient depression in the Southern Uplands, floored partly with Carboniferous and partly with Permian strata [178, 313]. The hills on either side are formed of Silurian rocks, and at Dumfries are nearly six miles apart, the

intervening low ground being covered with Permian deposits and "drift." About six miles north from Dumfries, however, the hills on either side draw together, the Permian rocks cease, and the Nith flows for about three miles through a series of ravines in Upper Silurian (Llandovery) greywacke and shale. The valley then once more expands into a wide basin, which is filled with Carboniferous and Permian Sandstones, and some volcanic rocks presumably of Permian age [335, 358]. The village of **Thornhill** stands nearly in the centre of this basin. Looking westward to the left the traveller can see how marked is the contrast between the outlines of the craggy Silurian hills and the smooth undulating surface of the younger drift-covered rocks of the basin. Beyond **Carronbridge** Station the railway runs through a tunnel cut in the Permian volcanic rocks and Carboniferous sandstones, and then strikes for the Nith, which is now seen on the left hand far below, flowing in a deep narrow valley cut out of the Silurian strata. A little below the mouth of the Menoch Water the Upper Silurian strata give place to representatives of the Lower division of the system, but without any marked change in the topographical features. The Silurian hills now once more retire on either side, and a wide basin of Coal-measures lies between them, forming the **Sanquhar** coalfield [313, 317, 333]. Several necks of volcanic agglomerate in the neighbourhood of Sanquhar mark the positions of volcanic vents of Permian age. On the south-west side of the basin the Coal-measures lie unconformably on the older rocks of the hills; but on the north-east side, the boundary-line is a fault with a down-throw of about 1200 feet, some of the highest parts of the Coal-measures being thereby brought down against the bases of the Silurian hills [Fig. 87]. About two miles to the east of **New Cumnock** the line of railway emerges from the Southern Uplands into the Midland Valley by the course of the Nith, which here forsakes the Ayrshire lowlands and strikes abruptly into the uplands. About midway between New and **Old Cumnock** a small loch may be seen on the right. It lies on the watershed (635 feet), and after heavy rains discharges both into the Firth of Clyde and the Solway. At Old Cumnock the railway crosses the Lugar Water, which is fed by a group of large streams (Glenmore, Guelt, and Gass) that descend from the high grounds on the north side of the Silurian hills, and flow north-westwards to the edge of the great peat-bog of Aird's Moss. Five miles farther on, from the lofty viaduct across the River Ayr, a glimpse may be obtained of the deep ravine cut by that river through the Permian

volcanic rocks and red sandstones which lie in the centre of the Ayrshire coalfield [358].

As the train gradually descends into Ayrshire the picturesque mountain group of Arran may occasionally be seen far to the left, rising from the opposite side of the Firth of Clyde [200]. The numerous coal and iron works of **Kilmarnock** show how much the aspect of the district has been changed by the development of its mineral wealth. From Kilmarnock northwards to the Clyde (Sheets 22, 30) the greater part of the surface is covered with volcanic rocks which occupy two marked platforms among the Lower Carboniferous formations. One of these lies below the Carboniferous Limestone, and the other at the base of the Coal-measures. It is the andesites, diabases, and tuffs of the lower series which crown the ridges from Ardrossan to the Clyde, and extend likewise along the east side of the valley followed by the railway from Kilbirnie to Johnston. Further reference to this portion of the country is made at p. 483. At **Johnston** the railway quits the narrow valley of the Black Cart Water and strikes eastward, skirting the platform of glacial clay with Arctic shells at **Paisley** [400], and then the alluvial flats of the Clyde till it reaches Glasgow.

6. Edinburgh and its Neighbourhood

(Sheets 32, 33, 40, 41, 31, 39)

Edinburgh is the best centre for seeing the scenery and geology of the eastern half of the Midland Valley.[1] The visitor should begin with a bird's-eye view of the country from one of the hills of the town—the Castle Rock (Mons Meg Terrace, 437 feet), Calton Hill (355 feet), or Arthur's Seat (823 feet). The whole region from the top of Ben Lomond, 60 miles away on the western horizon, to the May Island, 30 miles to the north-east; and from the crest of the Ochils on the north to the far heights of Tweedsmuir on the south—a total area of about 2000 square miles—is spread out as in a map around him. Looking westward up the valley of the Forth the tops of the Highland mountains rise along the sky-line from Ben Lomond on the left through the range of the Trossach Hills, Ben Venue, Ben

[1] The *Geological Survey Memoir* on the Geology of Edinburgh is out of print; but a new edition is in preparation. The *Memoirs* on East Lothian and on Eastern Berwickshire describe the geology of the ground to the east of Midlothian. A *Memoir* on the geology of Central and Western Fife is now published.

Aan, and Ben Ledi, to Stuc-a-Chroin and Ben Vorlich on the right. Turning in the opposite direction, his eye can take in the whole line of the Southern Uplands from the heights of Tweedsmuir, which appear faintly on the southern horizon, immediately to the left of the Pentlands, eastward through the group of the Moorfoot Hills to the far end of the Lammermuirs, above Dunbar. Between these two limits of the Midland Valley the wide intervening region displays most of the characteristic features of Scottish lowland scenery, which may readily be connected with geological structure. To the west above the valley of the Forth at Stirling the volcanic rocks of the Old Red Sandstone [356, 366] are seen to mount abruptly into the conspicuous lion-shaped hill of Dumyat, the most westerly spur of the Ochil chain, whence they extend eastwards as a continuous range of high ground, until cut off from view by the nearer group of the Lomonds [363, 384, 385]. The corresponding belt of Old Red Sandstone and volcanic rocks on the southern side of the Midland Valley comes much nearer to Edinburgh. It constitutes the chain of the Pentland and Braid Hills, which advance to the southern suburbs of the town. A striking contrast is presented by the nearer landscape on the eastern and western sides. From the top of Arthur's Seat the whole Carboniferous basin of Midlothian can be seen stretching eastwards to the base of the Southern Uplands—a wide rolling plain, with no more marked feature than the Roman Camp Hill beyond Dalkeith, formed by the uprise of the thick lower limestones. With the exception of some trifling dykes, not a single protrusion of igneous rock occurs in all that area. To the west and north, however, the Carboniferous formations abound with eruptive material, some of which was ejected as lava and ashes during the accumulation of the strata among which they are intercalated, while other portions were subsequently injected. Hence the region presents a most diversified outline. All the hills and crags which rise so abundantly to the west of Edinburgh, and along the whole of the opposite side of the Firth of Forth, owe their prominence to the hard volcanic rocks of which they consist. About eight miles to the westward the two diabase crags of Dalmahoy form a conspicuous landmark. To the right of these come the ridges of Ratho, Craigie, and Corstorphine. From the Calton Hill an excellent view may be obtained of the whole range of volcanic hills of Fife. These begin on the west with the Saline Hills—a group of cones which, projecting in front of the line of the Ochils, mark the position of volcanic vents of the Carboniferous Limestone

period [381]. From the narrows of the Firth, crossed by the Forth Bridge at Queensferry, eastward to Kirkcaldy, a continuous belt of volcanic hills extends, mounting into abrupt, truncated, conical hills at Burntisland, where some of the chief eruptive vents lay, the most conspicuous being the Binn, which rises immediately behind the village. Beyond these a high, flat-topped hill appears on the northern sky-line, with a steep western front, and passes eastward under two lofty conical eminences. Below that steep western front lies Loch Leven [385], and the two cones are the East and West Lomonds of Fife [363, 384]. Far to the east the cones of Largo Law [358, 363, 381, 382] and Kellie Law mark the sites of two of the numerous volcanic vents in the eastern part of Fife. All the islands in the Firth likewise consist either wholly or chiefly of erupted rock. On the southern side of the Forth the traveller sees along the eastern horizon the Lower Carboniferous volcanic group of the Garlton Hills, with Traprain Law, North Berwick Law, and the Bass Rock, while on the western horizon he can mark a corresponding series of volcanic rocks rise from the plain of the Forth at Stirling into the flat-topped Campsie Fells, above which the top of Ben Lomond appears.

In the immediate neighbourhood of Edinburgh, the localities best deserving of the time and attention of the geological visitor are Arthur's Seat, Corstorphine Hill, Blackford, Braid, and Pentland Hills.[1] At **Arthur's Seat** a remarkably interesting group of volcanic rocks of Lower Carboniferous age forms the lower and northern part of the hill. The durable basalt-rocks run as prominent north and south ridges, while the softer sandstones, shales, and volcanic tuffs have been hollowed out into valleys. The usual ascent of the hill from the north side is along the crest of one of these ridges (the Long Row), between the valley of the Hunter's Bog on the west, and that of the Dry Dam on the east. The southern and higher portion of the hill consists mainly of a coarse, volcanic agglomerate, which fills a vent subsequently opened (possibly in Permian time) through the older ejections. The summit is a plug of basalt rising through the agglomerate, and sending veins into it, which are well seen on the west front. The Queen's Drive on the south side of the hill has exposed an instructive section of the agglomerate, from under which the prolongations of two of the ridges seen on the north side run

[1] The geologist will find the rocks of the neighbourhood of Edinburgh well illustrated by specimens, maps, and sections in the Collections of the Geological Survey displayed in the Museum of Science and Art, Edinburgh.

down to Duddingston Loch. At the west end of the section on the Queen's Drive, a well-preserved glaciated surface of rock may be seen, the striæ running in the direction of the narrow gully, through which the road has been made [389].

Corstorphine Hill [385] presents a much greater area of ice-worn rock along its summit. This may be seen by taking the road that crosses the hill from north to south. The locality is interesting to the geologist as one of the places where Sir James Hall first observed such markings, which he attributed to vast diluvial currents. The view from the top of the hill in all directions, but especially up the Forth, is particularly noticeable. The large quarries which have been opened on the ridge exhibit many of the characteristic structures of the larger and more coarsely crystalline sills of the district.

Blackford Hill is the most northerly prolongation of the great mass of volcanic rocks of Lower Old Red Sandstone age constituting the chain of the Pentland Hills. The bottom of its southern face has been well smoothed and striated by ice moving down the hollow of the Braid Burn. An interesting walk or drive may be taken by the road across the Braid Hills. These eminences consist mainly of fine felsitic tuffs filling up what appears to have been a great volcanic vent of the time of the Lower Old Red Sandstone. From many points of the road views are obtained of the Pentlands, the Highland mountains, Edinburgh, the Firth of Forth east to the Bass Rock and North Berwick Law, and the range of the Lammermuir Hills.

Pentland Hills [355, 356, 357, 362, 369, 386, 389, 402].—The influence of geological structure on topographical features is well illustrated in this range of hills, and may be conveniently seen in a single day's excursion. By taking the Caledonian Railway to Juniper Green or Currie, the geologist may cross the marked escarpment of Warklaw Hill, formed of the lowest basic lavas of the Pentland series, and reach the unconformable basin of Lower Carboniferous strata which runs into the hollow occupied by the Clubbiedean Reservoir. On the hills above, he will find a footpath which will lead him across the succession of orthophyric or felsitic tuffs and lavas, and the dark amygdaloidal andesites, with occasional intercalations of conglomerate and sandstone, to the Glencorse Reservoir, where he will join a road, along the side of which many good exposures of the rocks may be seen. If he follows this road eastwards, he will soon emerge from the hills and cross the line of fault which forms their eastern boundary. He may then either turn southward to Penicuik and take a train

thence back to Edinburgh, or return on foot by the road which skirts the eastern base of the Pentland range and commands fine views to east and south. If he chooses the latter route, he will be rewarded by some good sections of the lavas by the roadside near Hillend farm, and by some of the best kames in this district, which lie in the hollow to the right a little farther north. By taking the right hand where the road divides a little beyond Fairmilehead, he will have an opportunity of seeing some exposures of the peculiar pale tuffs of the Braid Hills. The view from the highest part of the road is one of the finest near Edinburgh.

Instead of turning eastwards by the Glencorse Reservoir, the geologist may strike westwards up the long valley which separates the Pentland Hills into two ranges. Some good sections are to be seen by the side of this road and in the streamlets which descend from the slopes on either hand. Where the road ends at Habbie's Howe a footpath strikes northward and leads to Bavelaw, whence a good road runs to the Caledonian Railway. Around Habbie's Howe and Bavelaw, interesting sections on the hillsides, in watercourses and old quarries, show the characters and relations of the Upper Silurian and the Lower and Upper Old Red Sandstone strata. The little ravine at Habbie's Howe is especially worthy of examination, likewise the fossiliferous Silurian shales south of Bavelaw Castle.

Of the more distant excursions within easy reach of Edinburgh the following may be recommended:—

(1) **North Berwick** (Sheets 33, 41).—To the east the coast presents a range of cliffs of volcanic tuffs of Lower Carboniferous age traversed by basalt dykes and cut into bays and stacks by the sea. The finest part of the coast is at and beyond Tantallon Castle. North Berwick Law [363, 382, 389], an old volcanic vent, shows a well glaciated front on its north side, where the protecting cover of clay and debris has been removed in the course of quarrying operations. The view from the summit of this hill on a clear day is one of the most extensive in the neighbourhood of Edinburgh. The Bass Rock [363, 383, 384, 431], probably connected with the same series of volcanic protrusions, is only about a mile and a quarter from the coast, and is best visited from Canty Bay.

(2) **Fife Coast** (Sheets 32, 40[1]).—Burntisland, on the opposite shore, is an excellent locality for observing the features

[1] This coast is minutely described in the *Geological Survey Memoir* on "Central and Western Fife."

of volcanic necks and sheets of basalt and tuff intercalated among the Lower Carboniferous strata. The Binn [381], which rises boldly above the village, is the pipe of an old volcano dissected by denudation, and presenting in its crater-like chasms and basalt-dykes a remarkable resemblance to the walls of a recent crater. The coast-line eastward to Kirkcaldy exhibits an admirable series of basalt-lavas and tuffs cut into promontories and bays by the waves. Further information regarding Fife will be found at p. 487.

(3) **Queensferry** (Sheet 32).—The Firth of Forth narrows here to not more than a mile in breadth, the opposite promontories being formed of intrusive masses of diabase. Similar rock appears in the island of Inch Garvie, which, lying in the middle of the channel, has been made use of as a foundation for part of the Forth Bridge. Along the shore for some miles beyond South Queensferry the shales, limestones, and sandstones of the Lower Carboniferous series emerge from beneath the cover of boulder-clay which conceals them inland. The whole range of the Trossach Hills, the Ochils, and the Saline Hills of Fife forms a noble panorama from these shores and from the Bridge.

(4) **To Stirling by Railway—Carse of the Forth** (Sheets 32, 31, 39).—Immediately after leaving Edinburgh, good views are obtained, to the left, of the northern part of the range of the Pentland Hills, and of Corstorphine Hill on the right. At Ratho Station, beyond the cutting through one of the eruptive masses of diabase that diversify this part of the Midland Valley, some ice-worn surfaces of rock may be seen on the side of the railway. A lofty viaduct carries the line across the valley of the River Almond into West Lothian. Immediately beyond comes a long series of cuttings in the Lower Carboniferous strata, with their associated volcanic rocks. Binny Craig, to the south, has been already [362, 384, and p. 458] alluded to. Binns Hill, to the north, conspicuous by the tall, round tower on its summit, marks the site of one of these volcanic orifices, and consists of tuff, with a central plug of basalt [Fig. 102]. Linlithgow stands in a depression on the line of a great mass of basalts and tuffs associated with the Carboniferous Limestone. These rocks swell out southwards and form the chain of the Bathgate Hills. The Loch of Linlithgow is probably mainly due to irregular deposition of the drift which, immediately to the west, attains a great thickness and covers all the low grounds. The ridges of sand and gravel are particularly conspicuous. One of these, an admirable example of a kame [400], begins near Polmont

Junction and continues for several miles to the westward. Where first seen, it forms a narrow, wooded ridge, often mistaken by casual travellers for the line of Antonine's Wall, which also runs near this locality. Before passing Grahamston Station, a good view is obtained on the right of the wide Carse of Falkirk [376, 400, 411]. An upper and older terrace, of which the surface lies about 100 feet above the sea, is traversed by the railway at Larbert and northwards. At Bannockburn Station the line descends to the level of the Carse [410], and runs along the platform of the 50-feet strand-line to Stirling. The bank that formed the coast-line, when the sea overspread the Carse, rises as a marked feature on the left hand as the train approaches Stirling. The striking views from Stirling are referred to on the following page.

(5) **To Stirling by Steamboat.**—By taking this excursion, a good opportunity is afforded of comparing the outlines of the two sides of the estuary of the Forth. In the first part of the voyage the main outlines of the geology of Fife and the adjoining islands can easily be followed. Above the narrows at the Forth Bridge the Firth widens out, and the ground on either side becomes less craggy. To the west of Borrowstounness the hills on the southern side retire inland from the Firth, and allow the broad plain of the Carse of Falkirk to extend westwards up to Stirling. The upper edge of this platform is about 50 feet above the sea. At Kincardine, where the estuary may be said to merge into the river, relics of the 100-feet platform of marine erosion may be seen. The two hills of Airth on the south side of the river must have been islands in the middle of the channel at the time when the Carse was in course of formation. Above Alloa the river winds in a series of serpentine curves, known as the "links" of Forth. The high grounds on either side begin to draw nearer. On the north, the range of the Ochil Hills rises abruptly from the plain of the coal-field (which has been brought against it by a powerful fault shown in Fig. 97), and shows on its southern front the alternate bands of andesite and volcanic conglomerate of which its hills are composed. This structure is particularly well displayed on Dumyat. To the south the long line of the Campsie Fells slopes down into the plain, flanked on the eastern side by the great sheet of diabase which forms the line of lower hills that terminate in the rock of Stirling Castle.

From the foot of Stirling Castle rock to the foot of the Abbey Craig (which is a continuation of the same ridge), the Carse is a mile in width, and the Forth winds across it in wide loops.

Immediately to the west, however, the valley expands again to a breadth of more than three miles. The floor of this broad flat consists of the 50-feet terrace, which runs up to Gartmore—a distance of 17 miles above Stirling. Thus at the time when the land stood at the level of this terrace the estuary of the Forth wound inland for more than 25 miles above its present head. The thick peat-mosses which once covered most of the Carse are still to be seen in the upper part of the valley, though even there they have been in great measure reclaimed and turned into arable land [376, 400, 411, 421].

The visitor, if the day is clear, must on no account omit to see the panoramic view from Stirling Castle. The peculiar position of this eminence in the middle of the great depression of the Forth allows it to command one of the most extensive landscapes in Central Scotland. Along the south side of the valley, as we look westward, rises the lofty escarpment of the volcanic sheets of the Campsie Fells [362, 366, 382, 386]. Far to the west, beyond the flat plain of the Forth, the eye can follow the array of Highland peaks, till they are cut off by the high ridge of Old Red Sandstone forming the Braes of Doune [160, 236, and Fig. 46]. The most conspicuous on the left of the range is Ben Lomond, next comes Ben Venue, then in succession Ben Aan, Ben Ledi, and Ben Vorlich, while some of the higher peaks farther into the Highlands appear here and there beyond the nearer mountains. The links of Forth lie stretched out as in a map at our feet. Beyond them, to the north, the Ochils sweep boldly out of the plain, and stretch far to the east, in a line of precipitous slope on which the successive escarpments of their volcanic sheets form lines of parallel crags. Then come the volcanic cones of the Saline Hills in the west of Fife [381, 382], the ridges of Queensferry and West Lothian, and, far to the east, the lion-shaped Arthur's Seat towering above the faint smoke of Edinburgh.

Many other interesting excursions may be made from Edinburgh as a centre. Among these the following may be mentioned: (1) Through Fife by railway to Largo [358, 363, 381], and thence along the coast to St. Andrews, where excellent examples of volcanic vents may be seen on the shore, and where the influence of volcanic rocks in the topography of the Lowlands may be studied (p. 487); (2) To Dollar and Alloa, where the Ochil Hills in their geological structure and topographical features present many instructive features, and whence the Saline Hills may be reached; (3) To the Falls of Clyde, and the gorge of the Mouse

Water [357, 377, 379, 380, 403]; (4) To the Southern Uplands. As this last excursion opens up a wide district of the country, some more detailed information regarding it is here given.

7. Peebles, Selkirkshire—Eastern Part of the Southern Uplands[1]

(Sheets 24, 23, 16)

The traveller who enters Scotland by any of the usual railway routes (pp. 451, 453, 456) has an opportunity of seeing from the train some of the more prominent features of the Southern Uplands [309, 327]. If he would seek further acquaintance with the scenery of this region of Scotland, he can make an excursion into the south-eastern counties, where he will find many lines of road leading to the most typical localities in the district east of the Nith. This area can be easily reached from Edinburgh, or it can be visited by halting at Hawick or Beattock on the way north.

Taking the excursion from Edinburgh, the most convenient route is by Peebles, Innerleithen, Yarrow, and Moffatdale. For the first few miles the railway to Peebles traverses the Midlothian coal-field. Most of the cuttings along the line are in the thick covering of boulder-clay, sand, and gravel which overspreads this plain. The solid rocks are generally visible only in the water-courses where the overlying cover of drift has been cut through. One of the best views of the Pentland Hills is to be obtained from this line of railway, particularly from about **Leadburn** Station, whence the contrast between the smooth outlines of the conglomerate hills at the southern end [357, 386], and the more pointed forms of the volcanic hills farther north, already referred to, is well seen. Far to the south, beyond the conglomerate, the prominent conical hill Mendick marks the beginning of another volcanic belt of Lower Old Red Sandstone age, which swells out to a great thickness in Lanarkshire and Ayrshire.

Immediately beyond Leadburn Junction, the line of railway crosses the boundary fault, and enters the Southern Uplands. At first the ground is low and is covered with accumulations of sand and gravel arranged in kames, with little peaty hollows between them where small lakes once existed. The rock ridges hereabouts have been ground smooth by ice moving in a north-

[1] The geology of this region will be found fully described in the *Geological Survey Memoir* on the Silurian rocks of Scotland, 1899.

easterly direction. Keeping to the valley of the Eddleston Water, the railway runs obliquely across the strike of the Lower Silurian greywacke and shale, which, though for the most part covered with boulder-clay along the lower parts of the slopes, come to the surface along the tops of the ridges on either side. At Winkstone, about half-way between Eddleston and Peebles, a calcareous conglomerate and limestone of Caradoc age have been quarried on the east side of the valley. These strata are associated with a perlitic felsite marking the latest volcanic zone among the Lower Silurian rocks of this region. The Eddleston Water, it will be observed, rises almost at the very edge of the uplands, and flows southward across them, joining the Tweed at Peebles.

Peebles may be made a convenient centre for the exploration of the most interesting parts of the eastern half of the Southern Uplands. A line of railway follows the valley of the Tweed for many miles in both directions, and its slow trains and frequent stations allow the scenery to be leisurely studied. In the immediate neighbourhood, the most profitable excursion is to Cademuir, a hill 1359 feet high, lying to the south of the town [319 and Fig. 88]. From this eminence the observer looks away up the Manor Water to the dark recesses of Dollar Law (2680 feet), where a glacier once was nourished; while immediately below him lies a singular hollow, now without a stream of water, but not improbably once the channel of the Manor Water. If he is a good pedestrian he ought to ascend the valley of the Manor, look at the moraines at the head, and cross the watershed to St. Mary's Loch, where he may find quarters for the night, or he can pursue his journey either down Moffatdale or down Yarrow.

From Peebles an interesting excursion may be made to **Biggar.** The railway keeps the valley of the Tweed as far as Drummelzier, and allows the hills on both sides to be well seen. Where it quits the valley it strikes abruptly to the north-west, through a transverse depression which has been eroded in the Silurian hills, and communicates with the great Midland Valley beyond. It is through this depression that the waters of the Clyde might be turned across the watershed of the country so as to join the Tweed [378]. From Biggar a walk of less than two miles across this plain brings us to the Clyde. The hills to the north are formed of volcanic rocks belonging to the Lower Old Red Sandstone. To the south and south-west the Silurian rocks of the Southern Uplands rise boldly out of the low grounds at their base, their long straight front being defined by a north-east fault which has thrown down the younger formation against them.

The beautiful cone of Tinto to the westward has been already noticed (p. 457).

If the observer does not care to retrace his steps to Peebles, he may continue the exploration of the Southern Uplands by returning from Biggar to the Tweed at Broughton, and ascending that valley by the excellent old coach road. Little traffic now disturbs the quiet of this pastoral district; and it is less easy than formerly to obtain vehicular assistance when one's walking powers begin to flag. The tourist must consider this question before starting. For a good walker it is not too much, starting fresh from Biggar or from Broughton (where there is a railway station), to reach Moffat, or to cross over to St. Mary's Loch or Birkhill by the Talla Water in one day. But those who care may drive all the way to Moffat, or to the foot of Talla Linns, whence it is an easy walk over to St. Mary's or Birkhill.

The upper part of the Tweed, above Drummelzier, is a thoroughly typical valley of the Southern Uplands. Its narrowness, the steepness of its smooth, green sides, contrasting with the flat platform of alluvium through which the stream winds to and fro, the numerous narrow valleys that enter it from either side, and the height of the hills that encircle it, are features that impress us as we pass mile after mile through them [316-319]. The rocks for four miles above Broughton belong to the Lower Silurian series. They include the famous limestone of Wrae (two miles south of Broughton Station), in which the first fossils from the "schistus" of the south of Scotland were found by Sir James Hall in 1792. Near Stanhope the Llandovery grits and shales succeed, and continue to occupy all the rest of the district to the south. At Tweedsmuir Bridge the river foams down a set of rapids among projecting ledges of vertical greywacke. From this point the journey may either be continued up the Tweed, or deflected into the narrow glen of the Talla. The writer can recall many a pleasant day spent among these solitudes, with the shelter of old Wattie Dalgleish's cottage, at the foot of Talla Linns, to return to as night began to fall.[1] Immediately above the Linns—a picturesque gorge cut by the Talla out of highly-inclined greywacke and shale [345]—abundant mounds mark the moraines of the glacier that once crept down from the heights above Loch Skene. The route may be followed down the Megget Water to St. Mary's Loch, where quarters may usually be found at the hostelry there. Or if there is still time, the

[1] This valley has been entirely changed by the operations of the Edinburgh Water Works.

pedestrian may push up the Talla, cross over the col at the top, descend upon Loch Skene, and thence, either by the Grey Mare's Tail or the moors, to Birkhill, at the head of Moffatdale, where limited accommodation may be had. From the lower part of the Talla a track turns off to the right, up a narrow glen which leads to Gameshope Loch—a lonely tarn lying among moraines to the north of the Hart Fell ridge. The Loch Skene and Midlaw Burn moraines are described at pp. 345-347.

If no deviation is made at Tweedsmuir, the road will lead the traveller south-westward up the valley of the Tweed, which now becomes rather opener and more featureless. Due south Hart Fell rises in front along the sky-line to a height of 2651 feet; while the mass of Culter Fell (2454 feet) closes in the northern distance behind. The infant Tweed gushes out from a spring on the moor near the roadside. A little beyond this the watershed is reached, the highest point on the road being 1334 feet. Passing over a peat-covered moor, the road begins to descend into Annandale, and soon reveals the singular concavity at the head of that valley known as the "Devil's Beef Tub." The erosion of this hollow must have been begun at least as far back as Permian times, for a little above Moffat, breccia, believed to be of Permian age, is found lying on the floor of the valley [314, 336, 339].

Returning now to Peebles, whence the railway follows the line of the Tweed Valley eastward to the Cadon Water, until it strikes across through a pass among the hills into the valley of the Gala at Galashiels, we observe that the course followed by the river is rather oblique to the strike of the rocks. The successive bands of hard Llandovery greywacke or grit and more decomposing shale show themselves in the strips of craggy and smoother hillside, while on the floor of the valley the alluvial terraces of the river are well marked. Opposite Innerleithen the road turns off, by which an excursion may be made to **Yarrow** and **Moffatdale**, and this is probably the most generally convenient route to follow. Quitting the valley of the Tweed, where the river winds across broad flats of its own alluvium, the road follows for about a mile the narrower defile of the Traquair Water, along the base of the high uplands that culminate in Minchmoor (1856 feet); and then turns southward up the Newhall Burn, where some interesting evidence may be seen of the pre-glacial course of the stream, now filled with boulder-clay. The **Gordon Arms**, on the Yarrow, is a convenient centre from which to see the Vales of Yarrow and Ettrick [322, 336, 345]. **St. Mary's Loch** is the largest natural sheet of water in the eastern half of the Southern

Uplands [324]. How far it is a rock-basin or is due to the irregular accumulation of drift in the valley has not been ascertained. It receives from the north side the waters of the Megget, which rise in the moraine ground above referred to. It probably at one time extended southward to the upper end of the Loch of the Lowes as one continuous sheet of water, but the latter lake has been separated by the delta thrown across by the Whithope Burn and the Ox Cleugh Burn, which descend from opposite sides. On the low narrow strip of ground thus formed the little inn of St. Mary's (Tibbie Shiels's) has been built. The Vale of Yarrow continues for about three miles farther, when the watershed of the country is reached, which the road crosses at a height of 1080 feet. The little resting-place or "shepherd's sheelin" of Birkhill, unless in the height of the tourist season, may afford sleeping accommodation if the traveller would visit the old glacier ground of White Coomb and Loch Skene [345]. To reach that somewhat inaccessible tract, he may either strike over the moors in front of Birkhill or descend the main valley of Moffatdale until opposite the Grey Mare's Tail, and then climb the steep hill by the side of that ravine until he finds himself among the moraines. The streams of this district have cut deep gullies in the Upper Silurian strata, which are there seen to have been intensely puckered and driven over each other. Dob's Linn below Birkhill may be visited as affording a typical example both of the disturbance of the strata and of their erosion by running water.

In **Moffatdale** the most prominent features are the deep narrow glens on the north or right-hand side, particularly those of the Grey Mare's Tail, Carreifran, and Blackhope [317]. Conspicuous, also, are the gullies, torn by the streams, down the green slopes on either side of the main valley, and the cones of detritus spread out at the mouth of each of them on the plain below [Fig. 9].

From **Moffat** a short walk up the valley of the Annan will bring the traveller into the Devil's Beef Tub, already alluded to, as seen from above (p. 472). Another easy walk in the opposite direction will lead him to the Belld Craig Burn, where, in a picturesque dell, he will find an excellent example of post-glacial erosion in the red Permian sandstone [178, 314, 336]. In this district, also, he may observe the evidence of enormous denudation since older Tertiary time, as furnished by dykes [339]. One of these dykes crosses Annandale below Moffat. It may be followed across the hills either to north-west or south-east. In the latter direction the valley of the Glengap Burn, a tributary of

the Wamphray Water, near Moffat, shows the dyke as represented in Fig. 90. From Moffat a good pedestrian may easily reach the top of Hart Fell and descend upon the lonely old glacier tarn of Gameshope, whence he may pursue his way down the Tweed to Broughton, or return by the high road to Moffat, or cross over the hills to the west into the valley of the Clyde at Elvanfoot.

8. Edinburgh to Glasgow by Linlithgow and Falkirk

(Sheets 32, 31)

The first part of this route is the same as that from Edinburgh to Stirling (p. 466). At **Polmont** the lines of railway diverge. That to Glasgow passes on the south side of Falkirk, through some cuttings and a tunnel in the Coal-measures, and then runs parallel to the Bonny Water and to a remarkable depression which is filled with alluvium, and connects the valley of the Bonny with that of the Kelvin across the low watershed of the country. This hollow not improbably lies in the line of an ancient buried river-bed which has been traced under the boulder-clay in the coal-workings of the district from Bonnybridge by Larbert Junction to Grangemouth. Between Castlecary Station and Kirkintilloch numerous flat alluvial and peaty patches of ground may be noticed on both sides of the railway, lying in hollows of the drift ridges, and marking where once were lakes [403]. The terraced southern front of the Campsie Hills is well seen from the railway after passing Castlecary Station. Traversing some cuttings in the sandstones of the Carboniferous Limestone series at Bishop-Briggs, the train enters the tunnel at Cowlairs, and soon brings the traveller into the heart of Glasgow.

9. Glasgow and its Neighbourhood

(Sheets 30, 31, 38, 39, 22, 23)

Glasgow is an excellent centre for making acquaintance with the topography of the western part of the Midland Valley and of the South-western Highlands. The facilities for locomotion in all directions are so great that a large amount of ground may be traversed in a few days. Perhaps the first subject that will attract the attention of the geologist is the River Clyde and its relation to the topographical features of the region. At

Glasgow and for some distance both up and down the stream the alluvial platforms and terraces of erosion [400, 412, 414] may be observed. The youngest alluvial platform is that on which the lower parts of the city on both sides of the river are built. It is well seen from the railway to Paisley, being more than a mile broad on the south side of the Clyde. Alluvial haughs are also conspicuous above Glasgow as far as Cambuslang, and again above Bothwell. The 100-feet terrace of erosion extends up the valley nearly as far as the entrance to the gorge which the river has cut in the upper Coal-measures for about two miles below Bothwell. The 50-feet terrace runs down the valley below Glasgow, and is well seen on the north side from Partick to beyond Dalmuir, and on the south side at Paisley, to the west and north of which it forms a wide plain. The erosive action of the river is well seen in the Bothwell gorge, but still better in the ravine which contains the well-known Falls of Clyde [357, 377, 379, 380]. This interesting locality is best visited from **Lanark**. The traveller ought also to include in his examination the ravine of the Mouse Water [379, 403], and, if time allows, he may also embrace the remarkable series of kames at Carstairs [402, 403].

From various eminences in the immediate vicinity of Glasgow good views of the surrounding country may be obtained. Even from the higher crescents and terraces of the west end of the city, and from the College Grounds, glimpses may be had of the tops of the Highland mountains and of Goatfell in Arran. The **Cathkin Hills**, to the south-east, command the great Clyde coal-field, these heights themselves belonging to the volcanic zone which throughout the west of Scotland lies near the base of the Carboniferous system. The **Fereneze Hills** and **Gleniffer Braes** above Paisley, composed of similar rocks, afford good views across the western extension of the Clyde coal-field, northwards to the Kilpatrick Hills, with the distant Highlands beyond.

Among the many delightful rambles which may be taken from Glasgow there is only room here for a brief outline of the following :—

(1) **By River to Greenock.**—For many reasons this is one of the first excursions a stranger desires to make. The more prominent geological features are at some little distance from the river, but after sailing between the alluvial platforms and terraces of erosion for some miles, the geologist will observe that, as he approaches Old Kilpatrick, the rising grounds on either hand draw near to each other. These heights consist of

a portion of the great volcanic zone near the base of the Carboniferous system [362]. A fault here runs along the south-east side of the volcanic rocks, but the Clyde strikes without deflection across both the fault and the volcanic belt. This is the narrowest part of the valley below Glasgow. The hills on the right are particularly striking. Behind Bowling their terraced sides show the successive outcrops of the beds of lava and tuff of which they consist. As the valley gradually widens westwards, some conspicuous isolated hills appear on the right beyond the escarpments of the volcanic zone. These are volcanic necks, marking the sites of some of the vents which supplied the lavas of the hills to the east. Dumbarton Rock is the most prominent of them. Looking up the tributary valley of the Leven, the traveller sees Ben Lomond rising beyond the smoke of the manufacturing towns that have been planted along the course of that stream. Gradually the steamer retreats from the north shore, which, beyond Dumbarton, is comparatively featureless, being formed of Old Red Sandstone. On the south side, however, the same rocks which compose the Kilpatrick Hills rise into prominent heights, and stretch far southwards into Ayrshire. This volcanic series is one of the most prominent features in the geology and topography of the Clyde basin. The visitor who has time to ascend to the crest of the ridge above Greenock will obtain some idea of the broken kind of ground which the irregular disintegration of these volcanic rocks produces in the interior of the country. He will also be in a good position for seeing the outline of the western portion of the Highland tableland [Fig. 27 and p. 150].

(2) **To the Campsie Fells and Aberfoyle** (Sheets 31, 38, 39).—The railway through Strathblane enables the traveller to obtain a glimpse of the great northern escarpments of the Kilpatrick and Campsie Fells [362]. If he walks well and wishes to see more of these features, he should quit the railway at **Strathblane** Station, and slanting up the hills, continue for six or eight miles along the escarpment, until it makes its great bend above Fintry, when he may descend upon Balfron. The conspicuous detached hills which, beyond Strathblane village, stand out so prominently on the slopes in front of the escarpments, mark the position of some of the volcanic vents from which the lavas and tuffs of the plateau were emitted. The railway from Strathblane crosses the great plain of Old Red Sandstone that lies betwen the Carboniferous rocks and the schists of the Highlands. The wide peat-mosses may be seen

stretching away to the east [376, 421], and fine views are afforded of the back of the Campsie and Fintry Hills far eastwards to Stirling, and also of the remarkable hollow through which the River Forth flows in this part of its course. At **Aberfoyle** the effects of the great boundary fault are conspicuously seen in the craggy ridges of vertical Old Red conglomerate which contribute so largely to the picturesqueness of the locality [Fig. 47 and 119, 154, 160]. The River Forth crosses the line of the fault at Aberfoyle. If time allows, the visitor should follow an old hill road that ascends behind the village and crosses over the hills to Loch Vennachar. It will enable him to judge better of the singular contrast of landscape on the two sides of the dislocation, and will bring him to some good exposures of the slates and other rocks that form here the outer rampart of the Highlands. The carriage road between Aberfoyle and the Trossachs affords many pleasant views, and allows the geologist excellent opportunities of studying the characters of the metamorphosed sedimentary rocks which form the southern margin of the Highlands. The zone of probably Lower Silurian strata, wedged in along the edge of the Highland rocks [130, 355], is well worthy of examination.

(3) **To Loch Lomond, the Trossachs, and Callander** (Sheets 30, 38, 39).—This tour may be accomplished in one day, but is worthy of two or three. It may be taken either from east or west. If the traveller chooses the latter course, he may either take the train to Balloch on Loch Lomond and steamer thence to Inversnaid, or he may go by the West Highland Railway to Tarbet on Loch Lomond and cross thence by steamboat to Inversnaid. In passing by railway down the Clyde to Dumbarton, he sees on the way some of the features already described (pp. 475, 476). From Dumbarton the line bends up the valley of the Leven, and affords some good though rather too distant views of the terraced escarpment of the Kilpatrick Hills. From Balloch one of the lake steamers carries passengers up the loch, calling at different halting-places on either side, and thus giving good opportunities of seeing the topography of this largest of Scottish lakes [166, 206, 231, 254, 261, 270, 271]. The great boundary fault between Highlands and Lowlands runs through the first series of islands that are met with. It crosses the lake obliquely in a south-west and north-east direction. The conglomerate crag at the Pass of Balmaha stands immediately on the south side of the fault, which strikes thence across the islands of Inch Cailloch, Creinch, and Inch Murrin. A marked

band of slates along the Highland border is well developed at Luss, where it attains a great thickness and has long been quarried. The contrast between the comparatively smooth outlines of the slate-hills and the more broken contours of the harder mica-schists and grits to the north which rise into Ben Lomond will not fail to be noticed [231]. Another feature of interest in this part of the lake is to be found in the marine shells which occur in a layer of clay on the islands from Inch Moan to Inch Lonaig. These shells indicate a cold climate, and show that during some part of the glacial period the sea filled the basin of Loch Lomond. **Rowardennan** is the best halting-place for the ascent of Ben Lomond. If the day is clear, there is no Highland mountain the climbing of which is better repaid to the student of Scottish topography than this. Standing as it does at the very edge of the Highlands, and attaining a height of 3192 feet, it looks far and wide southward and eastward across the Midland Valley to the Southern Uplands and the North Sea, while at the same time it affords glimpses of ridges and summits many miles away in the heart of the mountains to the north. The intense glaciation of the country is instructively shown in the ascent of Ben Lomond [275, 374].

From **Tarbet** a walk of little more than a mile leads to the head of Loch Long [189, 231, 271, 275], whence steamers run to Glasgow. The glaciation of this pass is remarkable [271]. The deepest part of Loch Lomond lies between Tarbet and Inversnaid, where the soundings exceed 600 feet. Travellers who are going by the Trossachs disembark at Inversnaid. A most instructive journey, however, may be made by continuing in the steamer to the head of the lake at **Ardlui**, where the proofs of great ice-erosion are singularly fresh, and proceeding up Glen Falloch [175, 199, 296], either on foot or by the North British Railway (p. 492), among old glacier moraines to Crianlarich, the junction of the lines to Oban and Fort William.

From **Inversnaid** a steep road leads up Glen Arklet, parallel to a narrow gorge, which the stream has cut in the gnarled schists. A succession of old pot-holes [31] at different heights above the present bed of the stream mark the progressive erosion of the gorge. About a mile before reaching Loch Arklet a series of ridges, running up the south side of the glen, denotes the outcrop of some of the harder bands in the schist. The valley has been intensely ice-worn. As we ascend, moraine stuff becomes more abundant, until along the watershed between Loch Arklet and Loch Katrine, a fine series of moraine mounds

is to be seen, with large erratic blocks strewn about upon them. Ice-worn surfaces of schist are prominent at Stronachlachar, where a steamer waits to convey passengers down Loch Katrine [166, 232, 261, 262, 263]. This noble sheet of water runs in a curved course across the strike of the schists. On the south a group of massive grits and gritty schists rises into the huge mass of Ben Venue, crosses the glen of the Trossachs, and is prolonged north-eastward into Ben Ledi and the hills to the east of Loch Lubnaig [231]. On the north side of Loch Katrine mica-schists, with gentle southerly inclinations, sweep up into the hills that lie between this depression and the valley of Balquhidder. The comparatively recent formation of these lake-basins is proved by the dykes which cross them [166].

The gorge of the Trossachs affords a good opportunity of examining the topographical influence of the harder and more quartzose portions of the Highland schists. The tough, durable character of the material, and its tendency to break up along well-defined lines of joint, enable it to weather into bosses, crags, and knolls, with frequent precipitous faces and a general ruggedness of contour which is traceable alike in the bottom of the glens, along the hill-slopes, and upon the crests. The Trossachs lie in a band of these harder rocks, and owe to this circumstance their characteristic broken outlines. Another feature of interest will arrest the attention of the traveller. Loch Katrine has evidently been filled with ice, which rose high along the sides of the surrounding hills and moved downwards out of the lake through the gorge of the Trossachs and eastwards into the Midland Valley. The lake is a true rock-basin. All the islets and rocky ledges that rise along the rim from which its waters escape have been intensely ice-ground. Some admirable examples of ice-work may be seen a few hundred yards north of the Trossachs pier, along the side of a road, the making of which has removed the cover of moraine-stuff under which the ice-polish has remained preserved. Moraine-stuff, scattered erratics, and glaciated hummocks of rock continue eastwards past Lochs Achray [232] and Vennachar [154, 231, 254, 262], showing the size and long continuance of the glacier which once pressed outwards through this valley. One of the most conspicuous boulders, known as Samson's Putting Stone ($15 \times 6 \times 6$ feet), has been referred to [284] as forming a marked object on the crest of Bochastle Hill, on the left-hand side of the road between Loch Vennachar and Callander.

The traveller, in skirting the margin of Loch Vennachar, should

take note of the fact that the great boundary fault of the Highlands, as well as other dislocations, crosses obliquely under that sheet of water [154, 254]. Yet there is no chasm or other marked disturbance of the surface of the ground. Indeed, some little care is required to recognise distinctly the contrast between the contours of the highly-tilted ridges of conglomerate on the east side of the dislocation, and those of the slates and schists on the west side.

Callander, if the excursionist has time, is an excellent centre for making himself acquainted with the features of a considerable tract of the Southern Highlands, and also of the Old Red Sandstone part of the Midland Valley. The Trossachs and the lakes to the west are easily reached. To the north, the railway carries him in a short while to Loch Earn and Loch Tay. Behind the village an old hill road will lead him to the picturesque falls of Bracklinn and gorge of the Keltie (where an excellent section of the Old Red Sandstone is to be seen), and thence among the moraines of the glaciers that descended from the corries of Stuc-a-Chroin and Ben Vorlich into Glen Artney. A walk along the ridges of Old Red Sandstone to the top of Uam Var [366] and the great escarpment of Creag Beinn nan Eun [Fig. 46] is full of interest, both for what it reveals of the structure of these ridges and their bearing on the denudation of the Highlands, and for the views it affords of the Highland mountains on the one side and the Lowlands on the other. The Lower Silurian zone [130, 355] along the Highland border is well displayed in this part of its course.

Below Callander, as the train moves down the valley of the Teith, one of the most notable features is the size and abundance of the kames. These continue past Doune, and attain a wonderful development on the plateau traversed by the Allan Water. They are, perhaps, best seen on the left of the railway between Doune and Dunblane Stations. The Old Red Sandstone and masses of boulder-clay have been cut through in the making of the railway between Dunblane and **Bridge of Allan**. At the last-named station the line of railway emerges upon the broad carse-land of the Forth [376, 400, 411]. The detached Abbey Craig on the left, crowned with the Wallace Monument, is a prolongation of the intrusive sheet of diabase on which Stirling Castle stands. Behind it rises the terraced front of the Ochil Hills, consisting of successive sheets of various lavas and tuffs of the age of the Lower Old Red Sandstone [356, 362, 366, 370]. A line of fault traverses the bottom of these slopes, and brings in

the Coal-measures of the Alloa coal-field [Fig. 97]. In crossing the plain to Stirling, a fine view is obtained to the right up the valley of the Forth, the range of heights from Ben Lomond to Ben Ledi rising boldly above the broad alluvial expanse. (For Stirling, see pp. 466, 467.)

(4) **The Firth of Clyde** (Sheets 13, 14, 21, 22, 29, 30).—The excursions that may be made in this charming arm of the sea are so numerous that no space can be found here even for an enumeration of them all. For the student of scenery the chief features to be considered are the juxtaposition of characteristic Highland and Lowland landscapes, and the best way of seeing and contrasting each of these types. The northern and western coasts belong to the area of the Highlands, the eastern to that of the Midland Valley. The general aspect of the Highland table-land can be well seen from many parts of the eastern shores [114, 150]. The sea-lochs that open into the estuary of the Clyde are good examples of fjords. An admirable excursion for enabling the traveller to appreciate the features of these inlets is the circular one up Loch Lomond to Tarbet, whence a short walk to Arrochar [271] will bring him to the steamer down Loch Long (p. 478). This fjord crosses a succession of belts of schist, and shows their respective influence on the scenery, from the crags of the Cobbler and Argyll's Bowling Green down to the smooth hills above Dunoon [217, 231]. From Loch Long a striking traverse may be made up Loch Goil and through the defile of Hell's Glen to Loch Fyne [154, 189, 205, 206, 231, 271, 272, 275, 301, 302] at St. Catherine's. A less interesting route may be taken from the head of the Holy Loch through the glen occupied by Loch Eck [202] to Strachur on Loch Fyne. The glaciation of these valleys is full of attraction to the geological student. Moraines come down in some of the glens (as in Glen Messan at the head of the Holy Loch) to within a short distance of the sea-level.

The eastern side of the Firth of Clyde, from Gourock to Ardrossan, shows a long line of volcanic hills, which, above Largs, rise in terraced slopes to more than 1400 feet above the sea [362, 386]. The same rocks appear at the south end of the larger Cumbrae Island, form nearly the whole of the little Cumbrae, and also the southern end of Bute. In the two last-mentioned islands the influence of the successive sheets of lava in producing a step-like outline on the hills is singularly marked. The attenuated continuation of the same volcanic zone is well seen on the shore to the north of Corrie, in the Isle of Arran. From Stevenston a range of sandhills runs southward nearly as far as

Ayr [24]. In the interior the group of the Dundonald and other hills mark the positions of igneous masses that have pierced the Ayrshire coal-field (p. 452).

Bute and **Arran** (Sheets 29 and 21) are well deserving of a visit from the traveller who is interested in tracing the influence of geological structure upon scenery. The boundary-line between the rocks of the Highlands and the Lowlands runs obliquely across both islands. Hence the northern half of each of them lies within the Highland region, and the southern within that of the Midland Valley. The contrast between the aspect of the ground on the two sides of the boundary is especially marked in Arran, where the invasion of the Tertiary granite has disrupted the schists. The latter rocks preserve their usual tame contours, while the granite which protrudes through them rises into spiry peaks and notched crests [199]. The southern half of Arran consists of high rolling moorlands, formed in large part of eruptive rocks of probably Tertiary age which have disrupted and overlie the red sandstones and marls now regarded as Triassic [358]. Many of the details of Arran scenery are full of instruction. Such, for instance, are the corries and ballochs in the granite [Fig. 57]; the moraines [278, 299]; the erratics, especially on the eastern shore from Clachland Point to Glen Sannox [Fig. 81]; the dykes [361] which abound along the east coast, but still more at the southern extremity of the island, and the raised beach which forms the platform for the coast road from Brodick to Glen Sannox, and runs interruptedly round the island.

From the point of view of the history of the denudation of the island, one of the most remarkable features in the geology of Arran is the recently discovered volcanic centre [358]. The evidence there obtained shows that Rhætic, L assic and Upper Cretaceous strata once stretched across the southern half of the island, and were still in place in Older Tertiary time, when the igneous eruptions took place. Since then the whole of these strata have been removed from the region to the north and east of Antrim, except the fragments that have been preserved by falling into the great volcanic vent in Arran. This denudation has been effected since the date of the Tertiary eruptions, and thus a fresh and interesting confirmation is furnished of the conclusion drawn from the Tertiary dykes as to the age of much of the topography of Scotland. The Arran vent, with its masses of Secondary strata, may be examined on the hillsides immediately above where the road to Machrie diverges at the sixth milestone from Brodick.

Bute consists of two contrasted portions, the northern half being a continuation of the Highland ridges of Cowal, the southern half consisting of rocks similar to those of the opposite shores of Ayrshire and the Cumbraes [386]. The glaciation of the island is well marked [270, 278, and Fig. 74], and the raised beach forms a striking feature along the eastern coast [412, 414]. Above Rothesay one of the large east-and-west dykes crosses the island, and appears to be the same as one continued in the same line across Cantyre to Loch Tarbert [see 166]. The narrow sound between Bute and the mainland, known as the Kyles of Bute, presents many points of interest in connection with the glaciation of the country and the clays containing Arctic shells [399]. Loch Striven and Loch Riden [271] are also full of instruction in regard to the same geological features.

10. Ayrshire and Galloway

(Sheets 1, 2, 3, 4, 5, 6, 7, 8, 9, 13, 14, 15, 22, 23, 29, 30)[1]

These districts are best reached from Glasgow, unless the traveller takes them by way of Dumfries as he enters Scotland. The north of Ayrshire is indebted for most of its picturesqueness to the great number and variety of the volcanic rocks associated with the Carboniferous system [366, 386]. The long range of terraced hills which forms the chain of the Fintry, Campsie, and Kilpatrick Fells swells out to a great mass in the west of Renfrewshire, where some of the chief vents of eruption lay. In the high grounds about Misty Law, above Kilbirnie, some of these ancient vents have been dissected by denudation. The coast scenery is particularly charming from the Cloch Lighthouse to Portincross (Sheets 30, 22), this charm arising from the intermingling of sedimentary and volcanic rocks, from the platform of the raised beach, with the rocky, wooded bank that rises along its inner margin, and from the delightful sea-views across to Arran, Bute, the Cumbraes, and Argyllshire.

In descending into the Ayrshire coal-field we cross a zone of intrusive eruptive rocks near Troon, which rise into conspicuous hills at Dundonald. **Ayr** (Sheet 14) may be made the centre for several interesting excursions: (1) The ravines of the River Ayr,

[1] An account of the geology of Ayrshire will be found in the *Geological Survey Memoirs* on Sheets 14, 15, 22, and 23 of the map. The southern or Silurian territory is described in the monograph on "The Silurian Rocks of Scotland" already referred to.

particularly those in the Permian sandstones between Stair and Catrine; (2) the scenery of the River Doon up to Loch Doon and the great Galloway cauldron [347]; (3) Brown Carrick Hill, from which splendid views are had across the Bay of Ayr and over to Arran, Ailsa Craig, and Cantyre, and where examples of the Galloway granite boulders may be seen [343, 404]; (4) the coast from Ayr to Girvan. The picturesque promontories of Greenan Castle and the Heads of Ayr mark the position of volcanic vents of Lower Carboniferous age. Farther south the coast is formed of Lower Old Red Sandstones, conglomerates, and associated volcanic rocks. The finest part of the cliffs will be found at Culzean Castle.

Galloway [278, 315, 319, 337, 338, 341, 342, 344, 407] is not much opened up with railways, but several good, though now rather deserted, roads lead across it. The traveller who prefers railway communication will take the train by way of Girvan to Glenluce, and thence to Dumfries. But those who wish to enjoy this south-western region of Scotland will keep a good deal to the old roads, and either drive or walk. The coast-line south from Girvan abounds in interest and attractiveness. For the first few miles the road runs on a platform of raised beach eroded out of the tilted Silurian rocks [87]. It then mounts over the igneous mass of Bennan Head, which belongs to the remarkable volcanic zone that forms the base of the Lower Silurian formations now visible in the south-west of Scotland [310]. South of the Bennan promontory we descend once more upon the raised beach, where now a little outlier of Permian sandstone can be seen. South of Ballantrae a charming and instructive walk may be taken for five or six miles along the coast. The lavas of the Lower Silurian volcanic series are admirably exposed in shore reefs, which begin a little to the south of the mouth of the Stinchar River. These rocks, with the radiolarian cherts and tuffs associated with them, rise into picturesque cliffs, from the top of which the eye ranges over the wide firth, from the peaks of Arran to the headlands of the north of Ireland. The shore having proved too rocky and precipitous for road-making, the roadway leaves the coast after crossing the Stinchar, and striking inland to the head of Glenapp, descends this valley to Loch Ryan [313, 314, 330, 331, 334, 336]. The coast-line from Corswall Point to the Mull of Galloway is most instructive to the geologist as well as attractive to the lover of scenery. If time be limited, however, the best places to be visited are the three or four miles to the north of Port Patrick, and from Clanyard Bay to the Mull of Galloway [Figs. 24, 85].

From Stranraer, which lies on the low tract of land between Loch Ryan and Luce Bay, frequent railway communication is available for Dumfries. The railroad journey brings the traveller through much that is characteristic of Galloway scenery. From Glenluce he will catch a glimpse of the great sand-dunes there [24]. The section of the line to Newton-Stewart passes through a region of ice-worn knolls of rock, "drums" of boulder-clay [342], lochans, and peat. From **Newton-Stewart** (Sheet 4) some of the most interesting excursions in Galloway may be taken: as (1) Glen Trool, Merrick, and the southern and western edge of the great ice-cauldron of Galloway (Sheet 8); (2) to the top of Cairnsmore of Fleet; (3) to the raised beaches and alluvial platforms of Wigtown Bay and the picturesque cliffs of contorted Silurian rocks at Burrow Head; (4) by the old road across the moors, keeping the west foot of Merrick, among abundant moraines, and descending into the plains of Ayrshire at Maybole (Sheet 14). From Newton-Stewart to Castle-Douglas is by far the wildest portion of the whole railway route. Indeed, for rugged desolation, it is surpassed by few pieces of railway in the Highlands. Skirting the granite crags of Cairnsmore, through a wilderness of granite blocks and ice-worn knolls of rock, the traveller, for miles together, can see no trace of human occupation. Around the New Galloway Station the *roches moutonnées* are particularly fresh. **New Galloway** (Sheet 9) is the best point from which to visit the eastern rim of the Galloway cauldron and the corries on the sides of the Rinns of Kells [320], with their tarns and moraines (Loch Dungeon, Loch Harrow, etc.). There is also an excellent road which has been carried through the moraines, northward to Dalmellington.

From **Castle-Douglas** (Sheet 5) the branch line to Kirkcudbright should be followed if the traveller desires to explore the coast-line east of Kirkcudbright Bay, where some admirable sections of contorted rocks may be seen, and where the unconformable junction of the Upper Old Red Sandstone on the Upper Silurian rocks is well displayed [312, and Fig. 86].

Around **Dalbeattie** (Sheet 5) the chief topographical feature is the irregular hummocky surface produced by the weathering of the granite. Criffel, the most easterly of the granite bosses of Galloway, is best ascended from the east side, which may be reached, either from Dumfries, or by taking the coast road, round from Dalbeattie.[1] (For Dumfries, see p. 459.)

[1] See the *Geological Survey Memoir* on Sheet 5.

11. Edinburgh and Glasgow to Aberdeen

A choice of routes is available for this traverse of the country. The traveller may proceed on the Caledonian Railway from Edinburgh or Glasgow by way of Stirling, Perth, and Forfar, or on the North British Railway by the two great bridges across the estuaries of the Forth and the Tay, Arbroath, and Montrose.

(1) **By Stirling and Perth** (Sheets 39, 47, 48, 56, 57, 66, 67, 77).—The first part of this journey has already been described (pp. 466, 480). At Bridge of Allan the train enters upon the Lower Old Red Sandstone, and continues on that formation until it reaches the east coast at Stonehaven. Striking up Strathallan, the line crosses the Allan Water several times, and then bends eastward among abundant kames, skirting the northern front of the Ochil Hills on the right, and allowing good views to be obtained, to the left, of the range of Highland hills from Uam Var [366], eastward by Ben Vorlich to the heights above Dunkeld. After the watershed of the country is crossed between Blackford and Auchterarder Stations, the railway descends into Strathearn, still keeping the bold front of the Ochils to the right hand. The 50-feet and 100-feet strand-lines form conspicuous platforms from above Dunning down to the Firth of Tay. They have been considerably denuded, and alluvial terraces at three or more successive levels have been spread out upon them by the River Earn. After the railway has crossed the Earn beyond Forgandenny Station, it turns round sharply to the north, and is then carried in a tunnel through a band of volcanic rocks, which are prolonged across the Tay into Kinnoul Hill and the line of the Sidlaws [366]. **Perth**, which is now reached, may be made the centre for examining the structure and scenery of the Firth of Tay [37, 60, 365, 366, 370, 401, 413].

From Perth the line continues to ascend the valley of the Tay for some distance beyond Stanley Junction, until it crosses the river and strikes north-eastward along the centre of the great drift-covered hollow of Strathmore [113, 175, 366, 389]. The long line of heights to the right hand is the chain of the Sidlaw Hills. To the left, the Highland table-land rises above the plain of Old Red Sandstone. The places of the glens of the Ericht, Isla, and Esk can be observed from the distance, but their deep cañons [196, 380] can only be seen by being actually visited. **Blairgowrie** is the best centre for that purpose. The nearer views on both sides of the line present endless mounds of gravelly

drift, everywhere dressed off and levelled down by the streams that flow between them. Here and there these deposits take the form of well-marked kames, as at Glammis. The hollows have in many cases once been lakes, then marshes, and now are plains of peaty alluvium. The Loch of Forfar is one of the remaining sheets of water, but, as may be readily seen at its eastern end, it is now being rapidly filled up by the influx of sand and silt.

Stonehaven [62, 64, 364] is a good geological station for studying the crystalline schists and later granites of the Highlands on the one side, and the Lower Old Red Sandstone with its intercalated lavas on the other. These two formations are separated from each other by the great boundary fault which here runs out to sea and may be examined on the coast. The observer will find that the Old Red Sandstone strata to the south have been thrown on end for some two miles by the dislocation, and that at their junction with the Highland schists the two groups of rock have been so welded into each other that an actual sharp line of demarcation cannot be traced between them. The coast-line between this place and Bervie is one of the most picturesque parts of the eastern margin of Scotland, and abounds also in geological variety. For some distance beyond Dunnottar the vertical conglomerates of the Old Red Sandstone form a broken front of sea-washed precipices [64, 431]. The composition of these enormous accumulations of detrital material can be fully studied, likewise their intercalated lavas. The traveller by railway, after Stonehaven is passed, looking back out of the window on the right hand or seaward side of the carriage, will see the successive projecting headlands of conglomerate, one of them crowned with the ruins of Dunnottar Castle. Immediately beneath him, as the train dashes past the heads of narrow sea-worn gullies, he will note the gnarled and twisted schists, with their intrusive veins of pink porphyry, and, towards Aberdeen, their bosses of grey granite, until, making a wide curve across the River Dee, he is brought into the city of Aberdeen.

(2) **By the Forth and Tay Bridges** (Sheets 32, 40, 48, and thereafter as in route 1).—At Dalmeny the line passes through an interesting cutting in the oil-shale group of the Lower Carboniferous rocks, and then immediately emerges on the great Forth Bridge. From this elevated position the traveller has to the right a view of the Fife coast eastwards to Burntisland, with Inchkeith and the distant Bass Rock; to the left he looks up the firth, and may see the tops of the Highland mountains, including Ben Ledi and Ben Lomond, with the nearer range of the Ochil Hills.

At the north end of the bridge the train passes through some cuttings and tunnels in the thick dolerite mass of North Queensferry [19]. At Inverkeithing the line branches off eastward along the platform of the 100-feet terrace, and eventually reaches the edge of the firth close to Burntisland. The volcanic phenomena of this district are full of interest [381, 463, 465]. From Burntisland the railway runs eastward and northward across the county of Fife, and affords many good views of the singularly uneven surface of that county, produced by the abundant protruding masses of igneous rocks. The Lomond Hills [42, 363, 384, 385] are kept to the left after Markinch is passed, and then the line bends to the north-east, following a hollow occupied by the Upper Old Red Sandstone on the north and the Carboniferous eruptive rocks on the south. **St. Andrews** [23, 357, 387, 411], which lies off the main line, is well deserving of a visit from any one interested in coast scenery and the influence of geological structure on topographical feature. The phenomena of volcanic vents are illustrated in a clearer and more impressive way in the east of Fife than in any other part of Britain, for the rocks have been dissected by the sea, and are laid out in plan upon the shore. Of especial interest in this respect is the coast-line for a few miles to the east of St. Andrews, and also that between Largo and St. Monans [361, 363, 381]. These shores abound with erratic blocks, including many from the Highlands [407]. The raised beaches are also admirably displayed [410, 411].

At Leuchars Junction the train strikes across the eastern and narrowest part of the Ochil chain, following a line of transverse valley full of boulder-clay and kames. At the north end of this valley the escarpments of the volcanic series [370] may be seen ranging on both sides along the southern side of the Firth of Tay. From the Tay Bridge a view is obtained of the great anticlinal arch of the Ochils, but this is best seen from the upper or west end of the Firth [Fig. 99].

From Dundee the railway follows the coast for some miles, and affords views of the sandhills which flank both sides of the mouth of the Firth [60]. At Arbroath [62, 387, 414] it strikes inland, crosses a series of volcanic ridges which are a continuation of the line of the Sidlaw Hills, and joins the railway from Perth beyond Montrose. The rest of the route has been described at p. 486.

12. Aberdeen and the North-Eastern Counties

Aberdeen (Sheet 77) may be used as a centre for the exploration of the scenery of the north-east of Scotland. The following excursions from it may be more particularly recommended :—

(1) **The Coast-line south of the Dee** (Sheets 77, 67).—A ferry-boat at the mouth of the river will put the traveller down near the beginning of an interesting piece of rocky coast. He can follow the top of the cliffs by a footpath which commands views of all the interesting points, and from which he may almost anywhere descend to the beach. As the railway runs close to the coast-line, he can usually return by train. The sea has cut a series of admirable sections of the contorted Highland schists and of the intrusive dykes and bosses which have invaded them.

If the district at Stonehaven (*ante*, p. 487) has not already been visited, it may be conveniently examined from Aberdeen. The geologist will naturally seek the exposure of the great boundary fault [364] immediately to the north of the village. If time allows he should include also the first three or four miles of coast farther to the south. The great vertical bands of coarse conglomerate running as ribs cut out to sea, with their occasional interstratified sheets of lava, the gradual lowering of the angle of inclination as the strata recede from the line of dislocation, and the evidence of the enormous erosion of the sea, are additional elements of interest in a piece of coast-scenery which of itself is especially picturesque.

(2) **Deeside** (Sheets 64, 65, 66, 67, 75, 76, 77).—With the exception of a detour between Banchory and Charlestown, the railway up the Dee follows the course of the river, and affords good views of the scenery of this strath. From Ballater, where the railway ends, the journey should be prolonged to Braemar, whence some interesting excursions may be made. Of these the most frequently taken is that to the summit of Lochnagar [43, 44, 216, 234, 250]. A pleasant walk up the river will bring the observer to the Linns of Dee, and show him an admirable example of the way in which a Highland river erodes the schists of its channel. More adventurous is the excursion to the head of the Dee, Ben Macdhui, and the great corries [216, 233, 250]. This should not be undertaken without a guide, unless there are two or more travellers in company, and one of them carries and knows how to use the Ordnance Map of the district.

Another instructive excursion, only practicable for a good pedestrian, is to ascend Glen Callater (he can drive the first six miles to Loch Callater) over the ridge of Tom Buidhe, and then along the wide, high, moory summit to the top of Driesh [216], whence he can descend into Glen Esk, and find shelter in the little inn at Clova. In all these rambles among the higher Grampians he will everywhere meet with abundant evidence of the glaciers that once filled all the corries and glens of this region.

(3) **Peterhead and Fraserburgh** (Sheets 87, 97).—Except along the shore, there is little in this north-eastern part of Aberdeenshire to attract the lover of scenery. The coast-line from Peterhead [18, 65] south to Cruden presents the longest range of granite sea-cliffs in Scotland, and affords admirable opportunities for studying how this rock yields to the action of the sea and of the sub-aërial agents of destruction. North of Peterhead ranges of sandhills extend for many miles [23], and the Loch of Strathbeg bears a record of great changes in this part of the coast-line within the last few centuries. South of Fraserburgh rises the singular conical white quartzite Hill of Mormond, on the southern front of which the figure of a stag has been cut out of the layer of turf that coats the slopes. This white figure can be seen for many miles. From Fraserburgh westwards the shores are rocky but low, until the Old Red Sandstone sets in at Aberdour, when a noble range of precipices at once begins. Troup Head is a promontory of slate separated from the Old Red Sandstone by a fault [28]. At Gamrie the sea is eating into the rocks of the bay [27, 28, 65].

(4) **Banff, Macduff, Portsoy** (Sheet 96).—In this district also it is the coast-line that offers the chief attraction to the tourist. The coast east of Banff presents a succession of admirable sections of clay-slate, crumpled into intricate foldings, which appear both on the cliff and in detached islets and skerries [Fig. 36]. The shore to the west of Banff includes the well-known locality of Portsoy, and is full of interest to the student of petrography, but offers less attraction to the inquirer into the origin of topography. The Old Red Sandstone outliers on the coast at Cullen are singular relics of that formation, known locally as the "Kings of Cullen." The highest eminence in the neighbourhood, the Bin of Cullen, is a good example of the conical form assumed by a mass of quartzite [226].

13. Aberdeen to Inverness

(Sheets 77, 76, 86, 85, 95, 94, 84)

This is rather a long and uninteresting journey, and the trains are slow; but there are some points of attraction on the route. As far as Inverury the railway follows the line of the River Don. It then turns westward, and keeps to the north of the granite ridge of Ben-na-Chie (1696 feet), the highest summit in the north of Aberdeenshire [15]. Descending into Strath Bogie, it commands a view to the left of the Tap o' Noth (1851 feet), another of the landmarks in the north-eastern region of Scotland. At the base of the eastern front of that hill lies one of the patches of Old Red Sandstone which throw so curious a light on the history of the denudation of the Highlands [157]. At Huntly we enter the valley of the Deveron, but soon turn westwards, and passing Keith, descend by the valley of Mulben upon the flat alluvial haughs of the River Spey. The wooded bank on the right side of the river consists of Old Red Conglomerate covered in part with boulder-clay [18-20], and contains some picturesque ravines [Figs. 4 and 5].

Elgin (Sheet 95) is a good geological centre. Besides the line of railway from Aberdeen to Inverness, another line runs up the Spey and connects with the Highland Railway at Aviemore. A branch line goes to the coast at Burghead [65, 66], a second to Lossiemouth, and a third eastwards along the shore to Cullen, Portsoy, and Banff. The whole of the low grounds of this region are deeply buried under gravelly and sandy drift. The hills to the north of Elgin consist of reptiliferous sandstone, some exposed surfaces of which have well-preserved glacial striæ indicating an eastward movement of the ice. The boulders too are fragments of rock which have come from the west; one of these, known as the "Witch's Stone," measuring 16 × 12 × 6 feet, and consisting of Old Red Conglomerate, lies 2½ miles south-east of Burghead. A boulder of gneiss 15 × 8 × 8 feet rests on the sandstones at the east end of Loch Spynie. Many blocks of a remarkably coarse porphyritic gneiss (augen-gneiss), scattered along the southern side of the Moray Firth, have come from a parent mass of rock which runs through the hills behind Ben Wyvis.

Among the interesting excursions that can be made from Elgin the following may be mentioned: the rocky shore between Burghead and Lossiemouth [65, 66]; the coast-line between

Lossiemouth and the mouth of the Spey, with its remarkable array of old shingle Beaches [66]; the shore between Port Gordon and Cullen, with its good section of the quartzites and schists, and its picturesque remnants of Old Red Sandstone; the right bank of the Spey above Fochabers and the eroded pillars there to be seen of Old Red Conglomerate and boulder-clay [Figs. 4 and 5]; the sand-dunes of Burghead, Findhorn, and Culbin [22, 24, 66]; the gorge of the Findhorn in the Old Red Sandstone above Forres [194]; the Glen of Rothes, with its remarkable alluvial terraces [193]; the gorge of the Spey at Craigellachie; and the section of the schists at Mulben.

Forres may be made a pleasant centre for visiting some of the scenery and geology just referred to, such as the Findhorn Sands, and the gorge of the River Findhorn. The railway runs here through a great series of gravel and sand ridges or kames, and keeping the Old Red Sandstone heights of Culloden Moor to the left, enters Inverness.

14. Edinburgh or Glasgow by Railway to Fort-William

(Sheets 30, 38, 46, 54, 63, 62)

The journey from Edinburgh to Glasgow and from Glasgow to Dumbarton has been already alluded to (pp. 474, 477). Beyond Dumbarton the railway runs along the platform of the raised beach to Craigendoran Station, and then begins to ascend as it passes into the valley of the Gareloch [206, 231, 271]. The boundary fault of the Highlands is crossed a little to the west of Helensburgh, and the region of crystalline schists is entered. The line continues to rise high above the Gareloch, and crossing the ice-worn col at the head of that fjord, skirts the hill-slopes above Loch Long as far as Arrochar [271]. It then traverses the low watershed and emerges on the hillsides above Tarbet on Loch Lomond [166, 206, 231, 254, 261, 270, 271]. Fine views are to be seen both up and down this lake, of which the most picturesque part is the upper end. Beyond Ardlui the train traverses the old glacier valley of Glen Falloch [175, 199, 296]. At Crianlarich it crosses the line of the Oban Railway, and beyond Tyndrum [154, 296], turning northward among continued piles of glacier moraines, it skirts the base of the noble mass of Ben Doran. Moraines and erratic blocks are scattered in great

abundance along the route, and occasional glimpses of the quartzose flagstones are seen in streams and in railway cuttings.

From Bridge of Orchy Station the traveller can look down Glen Orchy, with its river winding along the bottom among abraded moraines and old alluvial terraces. Loch Tulla, with its clumps of ancient pine-forest, is passed on the left, and shows well how its upper end is being filled up by the quantity of detritus washed into it. Glimpses are from time to time obtainable to the left into the great corries of the Black Mount, while occasional remnants of the ancient Caledonian forest of Scotch firs diversify the slopes above the birches over the lower grounds. As the train advances it brings into view on the left side the fine cone of Buchaille Etive [233] and the mountains of Glen Coe [217]. At length it enters the wide and desolate Moor of Rannoch [154, 232, 296]. No road, track, house, or sign of human occupation can be seen. The line passes over ice-worn bosses of granite, mounds of moraine-stuff, and thick accumulations of peat full of tree-stumps [22, 419].

Beyond Rannoch Station the remarkable cone of Shiehallien may be observed to the right [226]. From the railway viaduct good views are afforded along Loch Lydoch to the great mountain group of the Black-Mount. Around Corrour Station the characteristic scenery of the Moor of Rannoch is well displayed. To the south-east the summits of the Glen Lyon mountains rise against the sky; the western horizon is bounded by the heights of Glen Etive and Glen Coe; while to the north-west the giant ridge of the Ben Nevis group comes into sight.

The route follows the valley of Loch Treig [288, 296], rapidly descending into Glen Spean. It brings the traveller close to some ice-polished rocks above the lower end of the lake, covered with moraine débris and huge erratics. He will see on either side one of the lower glacial terraces of Glen Spean, with a good section of its component sands and gravels.

From Tulloch Station the moraine-filled character of the valley of Glen Spean is well seen. As the mounds have been dressed off by streams, old alluvial terraces may be noticed at many different levels for hundreds of feet up the hillsides. The water-courses are every here and there cutting new channels in solid rock. The Parallel Roads now begin to be visible. The great terrace at the mouth of Glen Treig is specially conspicuous as we look back upon it. The remainder of Glen Spean traversed by the line is described on pp. 199, 275, 287-293. Emerging from the foot of the valley among endless moraines, we at last enter the level platform of the 50-feet beach and reach Fort-William.

15. Edinburgh or Glasgow by Railway to Inverness

(Sheets 40, 48, 55, 63, 64, 74, 84)

This traverse of the country affords glimpses of many characteristic features of Highland topography. Alternative routes are available to Perth. The journey by Larbert and Stirling has already been referred to (pp. 466, 486). Another line is supplied by way of the Forth Bridge (p. 487). After passing Inverkeithing, with its natural harbour girt round with crags and slopes of dolerite, the traveller finds himself carried along the flat platform of the 100-feet terrace north-westwards to Dunfermline, which has long been a great centre for coal-mining [411]. Turning eastward, the train near Halbeath skirts on the left the base of a rounded hill [Hill of Beath, 381], which is one of the best volcanic necks of the district. Traversing a busy coal-field, the line then bends northward, and at last, between Benarty on the right and the Cleish Hills on the left, emerges upon the plain of Upper Old Red Sandstone on which Loch Leven lies [385, 404]. Fine views are now obtained of the Bishop and West Lomond Hills with their capping of dolerite sills and their long green slopes [42, 363, 384, 385]. To the left, the rising ground forms part of the Ochil range, and consists almost entirely of volcanic rocks belonging to the Lower Old Red Sandstone. These rocks are well displayed in Glen Farg, through which the railway runs. They consist chiefly of dull purple andesites, with bands of volcanic conglomerate and tuff. After threading this picturesque valley, the line emerges at the north end upon the wide 50-feet beach of Strath Earn. Looking eastward, or to the right, the traveller will note the line of the anticlinal axis of the Firth of Tay [Fig. 99], while to the left he sees the back of the Ochils and the distant range of the Highland border.

Leaving Perth, we may take note that beyond Murthly Station the railway crosses the great boundary fault along the margin of the Highlands. But no hint of the existence of that important geological structure will be obtained from the topography. To the north of the fault lies a patch of Old Red Sandstone, probably occupying what was once a bay on the flanks of the Highland table-land [Fig. 47]. Hills of clay-slate now rise steeply on either side, and the Tay is observed flowing in the narrow defile of Birnam. The River Bran, which joins the Tay from the west, has excavated one of the most picturesque gorges in this part of the Highlands—a narrow, tortuous passage in the

schists with segments of old pot-holes high on the sides and a rush of foaming water below. Beyond the tunnel north of Dunkeld, the valley opens out, and the line of railway runs upon the alluvium of the river, the terraces of which can be seen on either side. Four of these terraces may be observed to rise one above another at Guay. At Ballinluig, where a fine alluvial terrace is displayed, the Tay Valley is quitted on the left hand, and in the distance in that direction the lofty cone of Shiehallien may be seen [226]. Beyond Pitlochry, another longitudinal valley, that of the Tummel, comes from the west, but following still the same line of depression the railway enters Glen Garry [154, 295]. At first the river is seen toiling through the narrow defile of Killiecrankie, but at the upper end of the pass, the valley widens, and alluvial haughs spread out on either side. Above Struan, however, the river changes its character and becomes an impetuous Highland torrent, foaming down a rocky channel. Good sections of the hard, flaggy quartzites ("Struan flags") through which it flows may be seen on every side. As the country becomes barer, mounds of detritus grow more numerous, until at last the traveller finds himself among large, well-preserved glacier moraines. These are more especially to be seen around the watershed in the Pass of Drumouchter [29, 202, 295], and especially in the railway cuttings. The mountains on either side (Athol Sow and Badenoch Boar) display many gashes torn down their sides by torrents which have pushed cones of detritus upon the alluvial plain below. The descent on the north side is comparatively rapid down Glen Truim, with crowded moraines, to Dalwhinnie [148]. Fine views are obtained into the hill ranges on all sides. A little south of Newtonmore Station, the railway enters Strathspey, and an opportunity is afforded of observing the vast piles of gravelly detritus that have been carried down this valley, and the numerous flat terraces into which the detrital material has been worked by the river in the gradual lowering of its channel [192]. One of the most striking fragments of terrace is that to the right, opposite Kingussie, on which the old Barracks of Ruthven stand.

From **Kingussie** an interesting traverse may be made by Laggan [187, 290, 293] into Glen Spean to see the parallel roads of Glen Roy and the glacier moraines of Loch Treig [288, 296, 493], and thence to the coast at Fort William. From **Aviemore** the higher Grampians may be reached [148, 216, 220, 232, 233, 250]. At this station the Highland Railway branches, the older line passing north by Grantown and Forres, while the

newer and more direct line strikes north-westwards across the valleys of the Dulnan, Findhorn, and Nairn rivers. The latter route is now the more usual for travellers who wish to proceed direct to Inverness. The railway gradually ascends from the Spey valley at Aviemore over mounds and terraces of gravel, good sections of which may here and there be noticed in the cuttings. The irregular forms of deposition of this material can also be clearly observed from the train—ridges and hummocks with occasional cauldron-like depressions filled with water—possibly marking where detached masses of ice from the retreating glacier of Strathspey were surrounded with gravel and gradually melted. The traveller will take note of the picturesque Scotch firs that have planted themselves on some of the mounds, and remain there as relics of the old forest of this region. At Carr Bridge the line passes through cuttings of boulder-clay, and thereafter ascends the ridge to the west and runs through the remarkable defile of the Slochd Mohr (big trench), which is a nearly dry valley cut across the watershed, and belonging to a system of drainage very different from that which now exists here.

On the western side of the watershed the line runs in some deep cuttings of drift, in which sections have been laid open of the peat-mosses that cover so much of the ground. Abundant trunks and roots of trees may be seen protruding from the bottom of the peat. As the train descends into the valley of the Findhorn, a view is obtained of well-marked gravel terraces in a broad expanse of the valley above where the river enters a rocky gorge. These deposits not improbably mark the site of a lake which existed here before the excavation of the ravine below [175, 198, 263]. The line runs for some distance on the surface of a terrace, and then strikes north-westwards across hills of gravelly detritus which seem to indicate a former course of the Findhorn. This coarse, well-rounded gravel is grouped into kames, and encloses sheets of water, of which the largest is Loch Moy.

At Daviot the railway reaches the valley of the Nairn, which here presents many features of geological interest, and may be conveniently explored from Craggie Inn. From the hillsides a noble panorama of mountains is visible across the Moray Firth, extending from the peaks above Glenstrathfarrar to the far Ord of Caithness. On the right side of the valley the hills show the junction of one of the newer bosses of granite with the mica-schists. On the left side the bottom of the Old Red Sandstone

is laid bare, with its massive sheets of conglomerate, made up mainly of the waste of the neighbouring granite. The glacial geology of this part of Strathnairn is specially attractive. On the right side of the valley, a couple of miles above the Craggie Inn, the observer will find one of the most remarkable groups of glacial ridges in the north of Scotland. Uniting some of the characters of kames and moraines, they run in nearly parallel lines for a mile or more down the valley, sometimes coalescing and enclosing tarns or alluvial flats, above which they rise steeply to a height of 40 or 50 feet. Huge blocks of coarse gneiss from the higher parts of the valley lie strewn along their surface. Boulders of the same material of enormous dimensions are crowded on one of the gravel platforms at the Free Church. Higher up the strath, moraine-mounds fill all the lower ground and ascend the hillsides, showing that a large mass of ice streamed out of the basin now occupied by Loch Duntelchaig.

The River Nairn at Daviot supplies another example of an alluvial expanse above a gorge. The broad plain above Craggie Inn was doubtless at one time a lake, which has since been drained by the cutting of the ravine in the schists below Daviot.

The railway now turns north-eastwards, descending for some distance the valley of the Nairn, until it crosses the river by a viaduct and then circles round the end of the ridge of Culloden Moor. As it runs along the northern slopes of this ridge it affords fine views across the firth to Ben Wyvis and the Sutherland mountains. The Black Isle with its successive inlets is visible from end to end. At last the line descends to the plain, and uniting with the older branch of the railway enters Inverness.

Returning now to Aviemore, we may follow the older main line of the Highland Railway. At Grantown the train quits the valley of the Spey, and the range of the Cairngorm Mountains, which is so striking a feature as one looks back up the valley, is soon shut out from view. The route now lies across a bare, bleak moor, roughened with endless huge mounds of sand and gravel, which are conspicuous between Dava and Dumphail Stations. North of the last-named station well-marked kames of coarse gravel, sometimes 60 or 80 feet high, continue down to the low country of Forres. As the train descends into the wooded valleys of the Dyvie and the Findhorn, the traveller will remember that this is the region of the famous Morayshire Floods [34]. The route from Forres to Inverness is referred to at p. 492.

16. Edinburgh or Glasgow by Caledonian Canal to Inverness

For this journey a choice of routes is available as far as Oban: viz. (1) by railway; (2) by steamer through the Kyles of Bute and the Crinan Canal; (3) by sea-going steamer round the Mull of Cantyre; (4) by steamer up Loch Fyne, or by coach from the head of the Holy Loch or the head of Loch Goil to Inverary, and thence by coach to the Oban Railway at Dalmally; (5) by railway to Balloch, steamer to Ardlui, and train or carriage through Glen Falloch (or by West Highland route) to the Oban Railway at Crianlarich. Each of these routes has its own attractions; but only the first two, which are the more usual, need be referred to here.

(1) **By Caledonian Railway to Oban** (Sheets 38, 46, 45).—The route as far as Callander has been already described (p. 480). Beyond that village the line enters the narrow Pass of Leny, and on emerging from its upper end skirts the shores of Loch Lubnaig [154, 254, 261, 262, 263]. To the left rise the coarse grits and conglomerates that form the rugged slopes of Ben Ledi [118, 154, 231, 263, 275]. On the farther side the same massive rocks are prolonged into the heights of Stuc-a-Chroin and Ben Vorlich. One of the Tertiary dykes from Loch Lomond comes over the north shoulder of Ben Ledi and crosses the middle of Loch Lubnaig [166]. The easterly dip of the rocks and their gentle inclination are well displayed along the Braes of Balquhidder, where limestones, mica-schists, and epidiorites form escarpments that face westwards and wind along the sides of the hills. Loch Voil evidently once stretched down to King's House, and possibly even to Loch Lubnaig. Its upper part has been nearly cut off from the rest and formed into Loch Doine by the delta pushed from the north by the Monachyle Burn. Vast piles of boulders are strewn about the hill-slopes at the head of Strath Ire [296]. The line of railway keeps far up the slope above the end of Loch Earn, and commands a good view of that sheet of water and the northern slopes of Ben Vorlich. It then turns up Glen Ogle, and has been carried through a line of shattered crags of schist until it enters Glen Dochart [154, 190, 296]. As we leave the Killin Station, the upper end of Loch Tay may be seen far to the right, with the huge mass of Ben Lawers [152] towering above it. For some miles beyond this point the most striking feature visible from the railway is the great abundance of the moraine-mounds that are scattered across the valley. The mountains on either side exceed 3000 feet in

elevation, and must have been important gathering grounds for the snow that fed the glaciers which filled up Glen Dochart. From **Crianlarich** [296], a pleasant walk through Glen Falloch will bring the traveller to the head of Loch Lomond and to the route already described at pp. 478, 492.

Descending Strath Fillan, the traveller meets with continued evidence of ice-action until, approaching Tyndrum, he comes upon the noble series of moraines which have been thrown down at the mouth of the glen that descends from the great corry on the eastern front of Ben Laoigh (3708 feet). The watershed of the country being crossed at a height of 874 feet, the railway turns down the valley of the Lochy amid a succession of moraine-mounds and alluvial terraces. Beyond Dalmally it crosses the wide delta which the Orchy and Strae have formed at this end of Loch Awe [136, 154, 189, 260], and then skirts the western shores of that noble sheet of water, turning westward into the arm that discharges the drainage of the lake through the Pass of Brander [139, 260]. The railway runs too close under the slopes of Ben Cruachan (3611 feet) to allow the imposing form and mass of that mountain to be appreciated; but as the traveller moves down Loch Etive and looks back he obtains from time to time a good view of the great Ben, so prominent a landmark in the Western Highlands. He will notice, too, the marked contrast of foregrounds when he leaves the schists and granites and enters upon the volcanic rocks of the Old Red Sandstone which extend along both sides of Loch Etive. The terraced forms of these younger rocks are particularly marked on Ben Lora, which rises as the outer eminence on the north side of the loch. **Connal Ferry** is the place from which the curious tidal waterfall may be seen [205]. On the north side of the loch at this point there is a fine example of the 50-feet raised beach [242], which here extends as a broad platform almost across the loch, and is partly covered with peat. The railway now turns inland, and, running through a picturesque district of crags and knolls formed of the volcanic rocks of the Old Red Sandstone series, makes a wide bend and descends to the pier at Oban.

(2) **By Steamer through the Kyles of Bute and the Crinan Canal to Oban** (Sheets 29, 28, 36, 44).—The more prominent features of the Firth of Clyde have been already (p. 481) described. The traveller who takes the usual water-route to Oban has an excellent opportunity of noting them. If the day is clear he may see the whole range of Highland hills from Ben Lomond to the Cobbler, and through Argyll's Bowling

Green to the rounded slate-hills above Dunoon [231]. The terraced volcanic ridges of Renfrewshire and Ayrshire [386] rise from the eastern side of the Firth, while to the south the cone of Goatfell [199, 232, 299] forms a conspicuous object. The Kyles (narrows) of Bute are a fjord-like passage between Bute and the mainland, consisting of two arms which meet at the northern end of the island, and are prolonged northward into the inlet of Loch Riden [271]. The lines of raised beach are well marked in the bays, also the contrast between the smooth outlines of the soft slate-hills at the entrance, and the more rugged forms of the harder grits to the north. The glaciation of the islets is likewise well preserved. Rounding Ardlamont Point, passengers have a good view of the granite hills of Arran. Loch Fyne is then entered [154, 189, 205, 206, 231, 271, 272, 275, 301, 302, and Fig. 83], the first halting-place being **Tarbert**, which is the point on the mainland whence communication is kept up with Islay and Jura [227, 242, 243]. At **Ardrishaig** there is a transhipment to the canal-boat which is in readiness to convey passengers and their luggage through the Crinan Canal. This traverse allows the observer to remark the numerous harder bands of grit and diabase which are bedded with the schists, and which protrude as ribs along the hillsides. He will also notice the wide peat-covered platform of raised beach which covers so much of the ground to the north of the line of canal. Beneath the peat lies a clay that encloses Arctic marine shells [398, 400]. At Crinan another steamer is in waiting, which soon makes its way out of Loch Crinan into the Sound of Jura. To the south the Paps of Jura are the most conspicuous heights. The numerous long parallel lines of promontories, islands, and sea-lochs mark the influence of the north-east and south-west strike of the rocks [189]. Passing through the Sound of Scarba, we come in sight of the range of the volcanic hills of Mull closing in the horizon to the north. The terraced volcanic hills of Lorne rise behind the islands, and are well seen around Loch Feochan. Keeping in the narrow channel between Kerrera and the mainland [83], the steamer at last sweeps into the land-locked Bay of Oban.

Oban (Sheets 44, 45) is the best centre for excursions in the West Highlands. Among the more instructive and interesting to the student of topography and lover of scenery the following may be recommended :—

(1) To Kerrera—Volcanic rocks of Old Red Sandstone resting on slates, raised beaches, glaciated rocks [277]. Good views of the Mull Mountains and of the hills behind Oban.

(2) Falls of Loch Etive [205], the raised beach of Connal Ferry, and the prolongation of the Lorne volcanic rocks in Ben Lora referred to on p. 499.

(3) Loch Feochan, and across the Lorne volcanic district to Kilmelfort.

(4) By train to Loch Awe, and up the lake by steamer to the southern end [136, 154, 189, 260, 296].

(5) Ballachulish, Loch Leven, and Glencoe—Raised beaches, glaciated rocks, slates extensively quarried at Ballachulish; andesites and other members of the Lorne volcanic series forming a wonderfully craggy group of mountains around Glencoe.

(6) Round the Island of Mull [141, 143, 164, 166, 234, 236, 238, 241, 243, 300]. This excursion occupies a whole day. According to the state of the tide, the route is either first through the Sound of Mull [139, 165, 244], or round by the southern coast of the island. The steamer keeps close to the basalt cliffs, which are thus admirably seen [82]. A halt is made at Iona, and again at Staffa [Fig. 65]. From the west side of Mull the marked contrast can be best seen between the flat cakes of basalt that form all the plateau country, and the conical or dome-shaped forms of the granitoid and other rocks which have disrupted the basalts [143].

(7) Fort-William and Ben Nevis [145, 180, 199, 217, 287]. This excursion may be prolonged so as to include Glen Spean, the "Parallel Roads," and the moraines of Glen Treig [288, 493].

Oban (or Fort-William) to Inverness by Caledonian Canal (sheets 44, 45, 52, 53, 62, 63, 73, 83).—In leaving Oban Bay good views are obtained of the conical granitoid hills of Mull to the west. Dunnolly Castle stands on a crag, which shows how picturesquely the Old Red Conglomerate weathers. By degrees Loch Etive opens out to right, with the peaks of Ben Cruachan towering above it. The verdant island of **Lismore** is an example of the greenness of the vegetation over the bands of limestone in the Highlands [229]. This island also supplies an excellent example of rock-ledge or *seter* cut at the level of the 50-feet terrace [243]. All along Loch Linnhe it will be observed that this strand-line in exposed places is a platform of erosion, and in more sheltered place generally a platform of deposit. As Loch Linnhe narrows northward its sides become steeper, and the mountains rise in elevation. During the halt at **Ballachulish** opportunity is given to note the remarkably glaciated rocks along the sides of Loch Leven [277], also the platform of the 50-feet raised beach, which projects from the north side like that from

the north side of Loch Etive at Connal Ferry [242]. In clear weather the range of mountain-views from the mouth of Loch Leven is almost unrivalled in the West Highlands. Note especially the peaks formed by the porphyries of Glencoe to the east, and the characteristic rugged forms of the schist mountains of Ardgower to the west.

At Corran Ferry Loch Linnhe is almost cut in two by another platform of the 50-feet raised beach, the level green surface of which contrasts with the dark rough mossy slopes on either side [242]. There are three distinct terraces here, one at 25, one at 50, and one at 75 feet. Another wide expanse of raised beach and moraine-mounds fills up the valley between Fort-William and Banavie. A projecting shoulder hides the top of Ben Nevis as seen from Banavie.

The long straight line of the **Great Glen** [115, 158, 178, 186, 257, 270] can now be appreciated as the journey is slowly made through it. Notice the great waste of the more decomposable schists that rise from the sides of Lochs Lochy and Oich, and the ice-worn surfaces of the harder rocks that cross the valley at Fort-Augustus. Loch Ness is an admirable example of a deep glen-lake [257, 258, 259]. Here and there, at its shallower parts, small deltas are creeping into it from the mouths of tributary streams. The Falls of Foyers are worthy of a visit as an illustration of the erosive power of a Highland stream, and before their waters were utilised for modern manufacture, were specially remarkable among Scottish cascades for the beauty of their forms and surroundings. Mealfourvonie (2264 feet), that rises so conspicuously on the opposite side, is one of the most elevated masses of Old Red Sandstone in the country [158]. Its position shows how old the valley of the Great Glen must be. Skirting some high terraces of alluvium, the canal strikes from Loch Ness to the sea, and brings passengers to the western outskirts of the town of Inverness.

17. Oban by Swift Steamer to Skye and Ross-shire

By this route some of the most characteristic and striking scenery of the west coast can be seen rapidly and to great advantage. The journey is taken through the Sound of Mull, between the terraced basalt slopes of Mull and Morven [141, 164, 165, 236, 238]. As we enter the Sound and look back, a splendid panorama of mountains meets our eye from Ben Nevis on the north, southward by Glencoe and Ben Cruachan to the

Paps of Jura. The contrast between the plateaux basalts of the northern half of Mull and the conical forms of the eruptive rocks of the centre and southern half is best seen from near Salen. Approaching the headland of Ardnamurchan we notice the remarkable veins of dark basalt and gabbro which have been injected into the light-coloured Secondary sandstones and limestones [Fig. 52]. Then the wilds of Moydart and Arisaig open out to view. In front the most conspicuous object is the Scuir of Eigg [141, 167, 171, 236, 237, 238]. The low ice-worn islets of Arisaig [91] form also a striking feature of the land-locked sea-loch at that place. To the west beyond Eigg the huge dark gabbro-cones of Rum [165, 234, 243, 300] rise out of the sea. Northward, if the day is fine, the whole range of the Cuillin and Red Hills of Skye [215, 234, 300] comes into view as the steamer turns past the northern precipice of Eigg and makes straight for Skye, while far to the west, beyond the headlands of Rum, the northern precipices of the basalt-plateau of Canna [170, 236] rise out of the sea. From this part of the course, also, the long level line of the Highland table-land can be advantageously seen [145, 150]. Keeping Rum to the left hand, and the southern point of Skye to the right, the steamer, on certain days, steers northward for Loch Scavaig [251, 300], and casts anchor at the head of that picturesque fjord. Time is allowed for landing and seeing Loch Coruisk, and the opportunity ought on no account to be missed.

Returning past the headland of Strathaird, with its abundant basalt-dykes traversing the pale Jurassic sandstones, the steamer makes for the Sound of Sleat, in traversing which views are afforded into the recesses of Lochs Nevis and Hourn, two of the wildest sea-inlets in the West Highlands [217, 230]. In the Kyles of Skye the passage is so narrow and tortuous that at first the traveller can hardly believe he is still sailing on a branch of the ocean. The scenery in Loch Alsh and around Loch Duich is characteristic of the mica-schists of the west of Inverness-shire [203, 229]. Beyond Kyle Akin we can observe some marked contrasts of scenery due to differences of geological structure. In front the low green flat island of Pabbay consists of Lias shales. Beyond it rise the red Torridon sandstone hills of Scalpay [139]. To the north similar sandstones form the Croulin Isles, and tower into the hills of Applecross. The Red Hills above Broadford [215, 300] are well seen as the steamer enters Broadford Bay (Sheet 71).

Beyond Scalpay lies Raasay, the highest point on which, the Dun Can, is a conspicuous outlier of basalt, and remains as a

monument of the enormous denudation of the Tertiary plateaux [164-173]. Looking up Loch Sligachan the traveller can contrast the surface of the basalt plateau on the north side of that inlet with the great granitoid cone of Glamich on the south, and the dark peaks of the Cuillins beyond the head of the loch. The cliffs of Skye, south and north of Portree, furnish good examples of the manner in which the Jurassic strata have been buried under and preserved by the basalt-sheets of the plateaux, and have been invaded by massive persistent sills (p. 505).

Broadford may be made a convenient halting-place for exploring the Red Hills and surrounding country. The shore of the bay affords continuous sections of the Lias limestones and shales traversed by innumerable dykes. To the south of the village the Cambrian limestone (with fossils) covers a wide space and near Kilchrist has been converted into a white marble by the protrusion of Tertiary granophyre through it. The Torridon sandstone is also well developed. A walk by the rough hill-road to Heast on Loch Eishort will bring the traveller to the Lias cliffs of that fjord, and in full view of the white quartzite hills of Sleat on the opposite side. He may prolong the walk by the shore to the deserted hamlet of Suishnish, below a great intrusive dyke and sill forming a bold crag. An old road leads from the hamlet northwards along the shore of Loch Slapin, first over Lias shales and then across the Cambrian limestone, which has been greatly metamorphosed by the granite of Ben Dubhaich. At the little bay of Camas Malaig the road turns inland past Kilbride. The singularly picturesque gabbro mountain of Blaven is well seen from this point of view, with the basalt escarpment of Strathaird in front of it. To the right rise the red granitic cones of Ben Cro and Ben Dearg. The road continues eastward upon the Cambrian limestone, crossed by numerous dykes, and descends at last upon Broadford.

A most interesting excursion may be made from Broadford by the coast-road to Sligachan. As the road drops down to Loch Ainort a fine set of moraine-mounds appears to the left. The characteristic screes of the granite hills are well seen, and the rock may be conveniently examined on the ridge between Lochs Ainort and Sligachan. The moraines of the Sligachan glacier go down to the edge of the loch.

Some varied and instructive excursions may be made from Broadford by boat when weather permits. The isle of Pabbay, with its abundantly fossiliferous Liassic shales and its network of basalt-dykes, well deserves a visit. The little islet of Guillemon

shows how a mass of gabbro yields at once to the action of the atmosphere and of the waves. Much more attractive is the island of Scalpay, which, though consisting mainly of Torridon sandstone, displays a tract of Lias at its southern end and an outlier of Triassic breccia on its northern coast. To the west of the main Liassic area a large mass of the bedded Tertiary basalt has survived. The sheltered shores of the west side of Scalpay show a succession of raised beaches up to the 100-feet terrace, of which some fragments remain.

The islands of Longay and Croulin afford excellent illustrations of the structure, colour, and topography of the Torridon sandstone. The scenery of the eastern margin of the Croulin Isles is specially notable for its beauty and variety of minor detail, the strata being traversed by joints, along which they have been carved into clefts and gullies. These fissures have been worked into caves and inlets by the sea, while above they are filled with foliage.

Portree (Sheets 80, 81) is a good centre for the exploration of the scenery of the northern half of Skye. Among the more interesting and instructive excursions that can be made from it the following may be recommended :—

(1) The Storr Rock—a series of pinnacles and crags which, owing to landslips, caused by the decay of the softer underlying Jurassic strata, have been split off from the main mass of the plateau-basalts. If the traveller is a good pedestrian he should continue the walk northwards by the top of the cliff to Stenscholl, where he can find accommodation and whence he can conveniently explore Quiraing. In this walk he will have the great escarpment of the plateau-basalts [141, 220, 236] on his left hand, and a sea-precipice on his right, formed of Jurassic sandstones and shales traversed by huge sills of basalt. Some of these sills form picturesque cliffs, such as that of the Kilt Rock, so called from its columnar structure, popularly compared to the plaits of a kilt.

(2) Quiraing—another and more striking example of the way in which the edge of the escarpment of the plateau-basalt has been broken up by the formation of landslips.

(3) Dunvegan and Loch Bracadale. The basalt precipices of Dunvegan Head are among the loftiest in Great Britain [82]. The two remarkable hills known as M'Leod's Tables are conspicuous objects all over the north of Skye [Fig. 48]. The coast scenery at the mouth of Loch Bracadale is well worthy of being explored by boat [Figs. 22, 23].

(4) Sligachan and the Cuillins. From Sligachan Inn a walk or ride up the Glen will allow the visitor to pass over a succession

of moraine-mounds with erratic blocks, and ascend into one of the wildest of the corries (Hart o' Corry) in the bare gabbro of the Cuillins. Impressive views are there to be seen of the extraordinary contrast between the forms assumed by that rock and those of the granitoid mass that forms the cones on the east side of the Glen. The junction of the two rocks, with numerous veins issuing from the pale granite into the dark gabbro, may be traced along the ridge of Druim an Eidhne to the south of the mouth of Hart o' Corry. Loch Coruisk [251, 300] can easily be reached by this route. A striking excursion from Sligachan is by the path over the col that leads to Loch Brittle and round into the gloomy Corry-na-Creiche at the back of Scuir-na-Gilean.

(5) Raasay Island—one of the most varied of the islands as regards geological structure. The northern end consists of Lewisian gneiss [121], which is there displayed in characteristic form. Above this venerable formation lies the Torridon conglomerate and sandstone [125], forming most of the central part of the island. The great eastern precipices display magnificent sections of the Jurassic formations of the Inner Hebrides, from the Triassic breccia up to perhaps the horizon of the Oxford Clay. A feature of special interest in the geology of Raasay is the abundance and variety of its igneous rocks of Tertiary age. Most of these are intrusive, and consist partly of sills and bosses of granophyre and partly of sills and dykes of basalt rocks. The tabular capping which crowns the Dun Can—the highest summit of the island—is an outlier of the plateau-basalts, and, as above remarked, remains as a signal memorial of the former wide extent of these lavas and of the enormous denudation which they have undergone.

The sail from Portree to Gareloch enables the traveller to compare the topography of the Torridon sandstone with that of the Lewisian gneiss in the island of Raasay [127, 222]. The former rock, easily distinguishable by its red tint and its bedding, offers a marked contrast to the bare bossy surface of the old gneiss. Rona Island is a prolongation of the same ancient gneiss. A view is now obtained up Loch Torridon. On either side of that singularly picturesque fjord the red sandstone mounts into lofty pyramidal hills, and if the day be clear, the peaks beyond the far head of the loch will be seen with their scalps of white quartzite [Fig. 31]. The Gareloch lies in the red sandstone, but with gneiss appearing along its inner shores.

Gareloch may be used as a centre for exploring the scenery of Western Ross-shire, or the journey may be continued thence

either to the railway at Auchnasheen or by Poolewe to Ullapool [297, 508, 509). Loch Torridon and Loch Maree are the two tracts especially worthy of visit in this district. They are further referred to below.

18. Inverness by Railway to Skye

(Sheets 83, 93, 82, 92, 81, 71)

Inverness, which can be reached by so many different routes, is a good centre for seeing the northern firths of the east coast.

The Beauly Firth, along the southern coast-line of which the railway runs, is fringed with raised beaches, which frequently have a steep bank of boulder-clay along their inner margin and wind into the bays on either side. A vast spread of marine alluvium is laid bare in this firth at low-water. Large tracts of this material, where it runs up tributary valleys, are now cultivated, and there is scope for extensive reclamation in this district. From the town of Beauly the picturesque falls of Kilmorack in the Old Red Sandstone are only two and a half miles distant. Between the heads of the Beauly and Dornoch Firths the ground is covered with a thick deposit of gravel and sand, which lies on boulder-clay and has been worked into kame-forms with enclosed tarns. These are well seen about Muir of Ord, near which also the 100-feet terrace forms a marked feature.

At Dingwall, which stands on the lower terrace or raised beach, and from which the old coast-lines of the Cromarty Firth are visible, the Skye railway strikes to the west up Strath Peffer, and through a narrow pass in the schists over into Strath Garve, where the scenery at once becomes characteristically Highland. The innumerable ice-worn knobs of schist, moraine-mounds, boulders, and sheets of heather present a singular contrast to the smooth cultivated slopes and flat fields of Strath Peffer. From **Garve** Station a coach-road runs north to Ullapool across the Dirie More [231, 297]. From the watershed on that road splendid views are obtained of the great red sandstone mountains of Dundonald [Fig. 61], and in the channel of the river that descends into Loch Broom one of the best cañons in Scotland is to be seen [198].

As the line of the Skye railway winds onward by Loch Luichart, an admirable display of *roches moutonnées*, moraines, and boulders is spread out on every side, while fine views are presented

of the mountains on the left, in which Scuir Vuillin forms the central mass. On the right lies the lofty and wild mountain-group of Fannich Forest [294], which must have been the centre of an important group of glaciers. The ice blocked Strath Bran and ponded back the drainage, which probably escaped westwards into Loch Carron [294, 295]. At **Auchnasheen** a remarkable group of ancient lake-terraces, belonging to this part of the glacial period, forms the most conspicuous object [Fig. 79]. From this station a good road leads to Loch Maree. **Kinlochewe**, at the head of that lake, is the most convenient place from which to see Loch Maree [125, 205, 224, 261, 277] and Loch Torridon [125, 126, 188, 298]. The visitor may drive from Kinlochewe through Glen Torridon [128, 236, 298] to the head of Loch Torridon, take boat down the loch to Shieldag, having previously telegraphed to the inn at Strathcarron to have a carriage waiting at Shieldag. From Strathcarron, an instructive excursion may be made to Applecross, where a remarkable group of cauldron-like corries has been carved out of the nearly horizontal Torridon sandstone. From the watershed, which is 2054 feet above the sea,—one of the highest elevations reached by a carriage-road in this country,—the glaciation of the region can be seen to great advantage.

Strathcarron being on this line of railway, the traveller can continue his journey thence to Skye. Or he may turn northward from Kinlochewe and drive by way of Poolewe, round Gruinard Bay [139] and the head of Little Loch Broom to the Ullapool Ferry—a charming route, now happily once more practicable for carriages. From Auchnasheen the railway to Skye crosses the watershed of the country [200, 294], and descends the short and rapid slope to the head of Loch Carron. The glaciation in this valley is exceedingly striking. The exposed rocks have been greatly ice-worn, while morainic detritus ascends far up the hillsides and has been cut into innumerable terraces, which are best seen by evening or morning light, when they appear as short interrupted lines sloping gently seaward with the general inclination of the valley. Some of the corries on either side of Glen Carron are full of large moraines, with abundant *roches moutonnées* and perched blocks. One of the most remarkable of these glens lies immediately to the north of Auchnashellach Station.

Loch Carron [37, 188, 206, 242, 297] is another example of a fjord being filled up at its upper end by the detritus carried into it by tributary streams. The 25-feet and 50-feet beaches form a wide plain, dotted with moraines at its upper end [299].

The 100-feet beach is strikingly developed to the west of **Strome Ferry** [242]. This station, or the terminus of the railway at **Kyle of Lochalsh**, may be made the centre for visiting Lochs Kishorn, Torridon, Alsh, and Duich, Glen Shiel, and the Falls of the Glomak. The steamboat journey to Skye has already been noticed, p. 465.

18. Inverness to Western Ross and Sutherland

(Sheets 91, 92, 100, 101, 102, 107, 108, 113, 114)

The branching of the railway at Dingwall affords a choice of routes to the remarkable scenery of Western Ross-shire and Sutherland. Allusion has been made to two ways of reaching Ullapool—one from Garve Station, which is the shortest and least interesting, and one by Auchnasheen, Poolewe, Gruinard Bay, and Little Loch Broom (pp. 507, 508). From Ullapool, a carriage may be hired to Loch Inver, or to Inchnadamph. The routes to these two places follow the same road as far as Drumrunie, and afford magnificent views of the great Torridonian escarpments of Coygach [Fig. 60]. The Loch Inver road turns to the north-west, under the cliffs of Coul Beg, and in sight of the strange peaks of Stac Polly. As it approaches Loch Inver it brings the traveller to one of the best points of view for Suilven. The Assynt road continues beyond Drumrunie across a series of moors at the base of the great masses of Coul Beg and Coul More. Suilven comes in sight as the road descends to Loch Veyatie. To the right of it is Canisp, and by degrees the heights of Ben More, Assynt, and Quinaig [Fig. 30] bound the view to the north and east. Skirting the foot of the Stronchrubie cliffs—the greatest limestone escarpment in Scotland,—the road soon leads to the Inchnadamph Inn, at the head of Loch Assynt.

The more usual way of reaching the west of Sutherland is from Lairg. Leaving **Dingwall**, the railway runs down the western side of the Cromarty Firth [37, 67, 194, 206, 207, 208, 282, 414, 507], and affords good views of the great alluvial accumulation at the head of that estuary, also of well-marked raised beaches (25, 50, 75, and 100 feet), which are seen about Dingwall, Invergordon, and Tain. Indeed the whole coast from Inverness to Golspie is one of the most remarkable tracts in Scotland for the number, extent, and perfect preservation of its raised beaches. The railway runs on a platform of raised beach between Invergordon and Delny Stations. At Novar is the deep

ravine of the Alt Graat [194]. Passing Invergordon, the traveller can look out to sea between the two Sutors that guard the entrance to the firth [208]. The 100-feet raised beach runs through the hollow between Nigg Bay and the Dornoch Firth, the latter estuary being nearly cut into two by the sand spit at Meikle Ferry. Raised beaches continue up the Kyle of Sutherland. Crossing the river upon well ice-worn bosses of rock and moraine-mounds, the railway runs up the steep ascent of the Shin to Lairg, whence views are obtained of Ben More, Assynt, and the mountains round the head of Loch Shin.

Lairg is the starting-place for three of the mail-gigs which cross Sutherland, viz.—

(1) To Inchnadamph and Loch Inver.—Nearly the whole of the journey is in the valley of Strath Oykil, which becomes somewhat monotonous before the traveller reaches the watershed and sees the strange pyramid of Suilven towering in front, and the mass of Coul More to the left [Fig. 60]. The drive from Inchnadamph to Loch Inver is one of the few in Sutherland where considerable tracts of natural wood enter as a marked feature into the landscape. The imposing mass of Quinaig rises in front and shows with striking clearness its threefold grouping of rocks—Lewisian gneiss, with overlying horizontal red Torridonian sandstones, and white Cambrian quartzite stealing up the eastern slopes to the summit of the mountain. The actual junction of the sandstone and gneiss may be noticed by the side of the road. On the north side of the mountain, where the gneiss rises into a prominent hill beneath the sandstone, a fragment is left of a pre-Torridonian topography [125, 126, and Fig. 30].

(2) To Scourie and Durness.—This is a long and somewhat tedious drive until the watershed of the country is reached. Thence, amid abundant glacier moraines, the descent is rapid down to Loch More, from either side of which the younger well-banded gneisses rise steeply against the sky-line. Ben Stack, [221], a huge mass of old Lewisian gneiss, at length comes into view, and the traveller enters upon a typical district of the most ancient rock of the British Islands [121 and Fig. 28]. From Scourie the red Torridonian sandstone cliffs of Handa Island [82] should be visited, while a most instructive excursion may be made to Lochs Glendhu and Glencoul, on the ridge between which a striking view will be obtained of the great thrust which brings the Lewisian gneiss above the quartzite. In the drive from Loch Laxford to Durness, fine views are obtained of the great line of quartzite escarpments from Arkle northwards. The traveller

who reaches Durness [22, 27, 34, 37, 128] should not leave without taking boat to Cape Wrath, under the great Torridon sandstone cliffs [80], and seeing the western sea-wall of Lewisian gneiss south of the lighthouse [Figs. 21 and 29]. He can arrange to drive back from Cape Wrath. If the weather is suitable, he should also view by boat the great quartzite cliffs of the Whiten Head [298]. The moraines at the head of Loch Eribol [298] can be seen if he drives round that inlet.

(3) To Tongue.—This traverse is chiefly interesting from the views it affords of Ben Cleithbric, one of the most imposing schist mountains of the north-west of Scotland, marked with prominent ribs by the escarpments of its schistose rocks that dip towards south-east. Ben Loyal [232], the most picturesque mass of granite in the same region, is best seen from the north side. Altnaharrow stands on a fine glacier-moraine which stretches down Strath Naver. From Tongue a good road eastwards into Caithness affords many fine views of coast scenery.

20. Inverness to Thurso, Wick, and the Orkney and Shetland Islands

The line of railway to Lairg has been already described (p. 509). Quitting the valley of the Shin, the line turns eastwards down Strath Fleet. Threading its way among old glacier-moraines, it reaches once more the terrace of the raised beach, at the base of the Old Red Sandstone hills, and then turns northward along the flat selvage of ground made here by the Jurassic rocks. The hill behind the Mound Station consists of Old Red Conglomerate so wonderfully ice-worn as to remind one of the sides of a Swiss glacier-valley, such as that of the Aar. At Brora conspicuous glacier-moraines come down to the sea [298]. At Helmsdale the railway leaves the coast and strikes into the interior. The quartzite mass of the Scarabin Hills forms the highest ground to the right. To the left, as the train moves onward, Ben Griam [158, 236] comes into sight, and as the line turns eastwards across the wide dreary moor of Caithness the giant cones of Morven [68, 157, 236] and the Maiden Pap close in the southern distance.

The county of Caithness offers little attraction to the geologist or the lover of scenery, except along its shores, which are eminently picturesque. The coast to the south of Wick abounds in striking cliffs and stacks [69, 70]. Those to the west of Thurso consist of similar rocks, and are equally impressive,

particularly at the Clett and Holburn Head [Fig. 13]. The stacks of Duncansby, consisting of red sandstone [Fig. 18], may be contrasted with those composed of hard-jointed flagstone.

From Thurso a steamer crosses to Orkney, where the Caithness coast scenery is repeated. The cliffs of the west of Hoy, however, with the solitary "Old Man" [Fig. 19], are much more imposing than any on the opposite coast of the mainland. From Wick a steamboat sails to Kirkwall and Lerwick. Shetland, though destitute of fine inland scenery, abounds in picturesque coast cliffs cut by the waves into the most fantastic forms [24, 74, 77, 119].

INDEX

THE END

Printed by R. & R. Clark, Limited, *Edinburgh.*